US Army Corps
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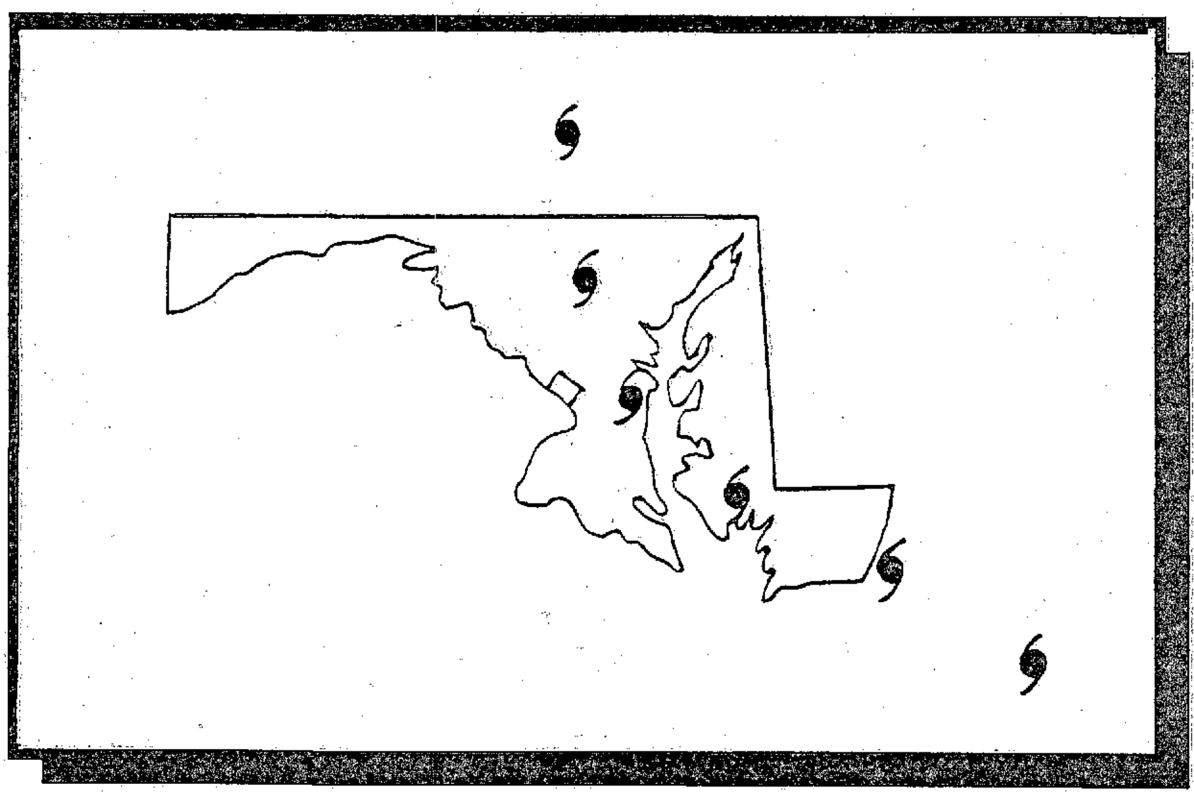
Maryland Hurricane Evacuation Study

Technical Data Report



Maryland Emergency Management Agency

Federal Emergency Management Agency, Region III

U.S. Army Corps of Engineers, Baltimore District

MARYLAND HURRICANE EVACUATION STUDY

Technical Data Report
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TECHNICAL DATA REPORT
MARYLAND HURRICANE EVACUATION STUDY

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MARYLAND HURRICANE EVACUATION STUDY

SUMMARY

Most extreme events in nature cannot be controlled, yet the human consequences may be affected dramatically by actions taken prior to the event. The Maryland Hurricane Evacuation Study was conducted in order to develop policies and plans to safely and efficiently evacuate people during a hurricane and to increase public awareness of hurricane dangers.

The study consists of five separate related analyses which produce data which define hurricane hazards and responses. The hazards analysis determines the magnitude and extent of hurricane related hazards including surge and winds. The vulnerability analysis identifies which areas are subject to the surge inundations which are defined by the hazards analysis. The behavioral analysis determines the probable public response to a hurricane threat, and the shelter analysis defines the existing public shelters and their capacities. Finally, the transportation analysis determines the time required for a safe evacuation in various hurricane threat scenarios.

The study provides several tools to the emergency management official for hurricane evacuation planning and policy development. Evacuation clearance times, which are determined by the transportation analysis, define the time required to clear all evacuating vehicles from the roadway network. Clearance times in the Maryland study area range from four hours in Worcester County in a minimum hurricane under the best conditions to over forty-four hours in Talbot County in a severe hurricane under the worst case scenario.

A second tool provided by the study is the county inundation map. For each county in the study area an inundation map is provided which shows which areas are expected to be inundated by storm surge for various hurricane strengths. Public shelters, hospitals, nursing homes, prisons, and trailer parks are located on each map as well. Maps showing hurricane evacuation routes and evacuation zones are also provided for Anne Arundel and St. Mary's Counties, and for each Eastern Shore county.

A final tool which is available to emergency planners is the Decision Arc Map/STORM set. The Decision Arc Map is a tracking chart with concentric arcs spaced at 20-nautical-mile intervals, and the STORM is a representation of an approaching hurricane. These two items are used together with the Hurricane Evacuation Decision Worksheet, contained in the technical data report, to determine if and when evacuation is necessary.

Although these tools, together with the technical data report, provide information concerning hurricane evacuation procedures, they do not make decisions for the emergency management officials. They are intended to be used only as guides, while the ultimate evacuation decisions rest with the officials.

ACKNOWLEDGEMENTS

This report was prepared by the Baltimore District, Corps of Engineers, under the general direction of Colonel Frank R. Finch, District Engineer. The work was conducted under the supervision of Dr. James F. Johnson, Chief, Planning Division, and Mr. Noel E. Beegle, Chief, Basin Planning Branch. The technical work and preparation of the report were performed by Mr. Richard R. Zingarelli and Ms. Lynne L. Galal. Ms. Ruby Jones provided technical assistance to the study, while Ms. Effie Hondrelis contributed clerical assistance. Administrative assistance was provided by the Federal Emergency Management Agency, Region III, by the Maryland Emergency Management Agency, and by the Maryland Department of Natural Resources. Special technical assistance for the study was provided by the National Hurricane Center and by the Emergency Management officials of the City of Baltimore and the counties involved within the study.

CHAPTER ONE

INTRODUCTION

More than 61 million people live and work within 50 miles of the Gulf of Mexico and the Atlantic Ocean, and the number is increasing at a rate three times greater than other areas of the nation. In addition, more than 53 percent of the nation's industrial base is located in coastal regions. As a result, more and more people are subject to the threat of a hurricane, but the vast majority have never experienced a major coastal storm.

This situation characterizes the State of Maryland, where the Chesapeake Bay and its tributaries have experienced rapid development of all types over the last 20 years. Residential communities, shopping centers, and industrial parks have expanded into rural or undeveloped areas. The Maryland Atlantic Coast has also seen growth, primarily in tourist and recreation related development in and around Ocean City. Although Ocean City has a permanent population of only 7,354 persons (1980 Census), it is visited by as many as 200,000 people on peak summer days.

Historically, Maryland has not had a severe problem with hurricanes. During the last century only three hurricanes have occurred in the region; the first in August 1933, followed by "Hazel" in October 1954 and "Connie" in August 1955. The 1933 storm was the most destructive ever recorded in the State of Maryland. It produced the highest tide of record throughout the Bay and caused significant damage along the Atlantic Coast. At Ocean City, the most destructive storm of record was not a hurricane, but the March 1962 "Northeaster".

There have been no major hurricanes in Maryland since the recent spurt of development began in the coastal areas. Most recently Hurricane "Gloria" (September 1985) was potentially very dangerous, and many areas along the Bay and the Coast were evacuated as a precautionary measure. However, with the exception of Ocean City, the effects of "Gloria" were negligible and did little to increase general public awareness.

To reduce the potential for large scale loss of life and damage to property, there is a critical need for policies, programs, and plans to achieve the wise use of flood-prone areas, to increase public awareness of hurricane related hazards, and to evacuate people when hazards are expected to occur. To address the latter area, a hurricane evacuation study was conducted for the State of Maryland.

Purpose

The purpose of the Maryland Hurricane Evacuation study is to develop detailed technical information for use by state and local governments to improve existing hurricane evacuation plans or to develop new plans. The study was conducted by the U. S. Army Corps of Engineers, Baltimore District, in cooperation with the Federal Emergency Management Agency (FEMA) and the National Weather Service.

Funding

The Maryland Hurricane Evacuation Study was funded by the Federal Emergency Management Agency and the U.S. Army Corps of Engineers.

Authority

This hurricane evacuation study was requested by the Maryland Emergency Management and Civil Defense Agency by letter, dated 27 February 1985. The authority for Corps of Engineers participation is the Flood Plain Management Services Program which was created by Section 206 of the 1960 Flood Control Act, as amended. Under this program, the Corps can use its technical and planning expertise to assist others in flood plain related matters.

FEMA's participation is authorized by the Disaster Relief Act of 1974 (Public Law 93-288) and Executive Order 12148, Federal Emergency Management, dated 29 July 1979. Section 201 of the Disaster Relief Act gave the President authority to establish programs and funding for assisting states and local governments in developing comprehensive disaster preparedness plans. Executive Order 12148 delegated these responsibilities to FEMA.

This study was conducted by the Baltimore District, U.S. Army Corps of Engineers, which provided the project management and technical assistance in accordance with U.S. Army Corps of Engineers publication, Technical Guidelines For Hurricane Evacuation Studies, November 1984, and Federal Emergency Management Agency publication CPG-16, A Guide To Hurricane Preparedness Planning For State and Local Officials, December 1984.

Description of Study Area

a. Geography. The study area consists of the Atlantic Ocean and Chesapeake Bay coastal areas of the State of Maryland. As shown on Figure 1-1, the study area includes Baltimore City, Ocean City, and the Maryland counties of Anne Arundel, Baltimore, Calvert, Caroline, Cecil, Charles, Dorchester, Harford, Kent, Prince George's, Queen Anne's, St. Mary's, Somerset, Talbot, Wicomico, and Worcester. While the District of Columbia borders the Maryland study region, the existence of a major flood protection project and a comprehensive emergency management plan for the District of Columbia warranted the exclusion of the City from the study.

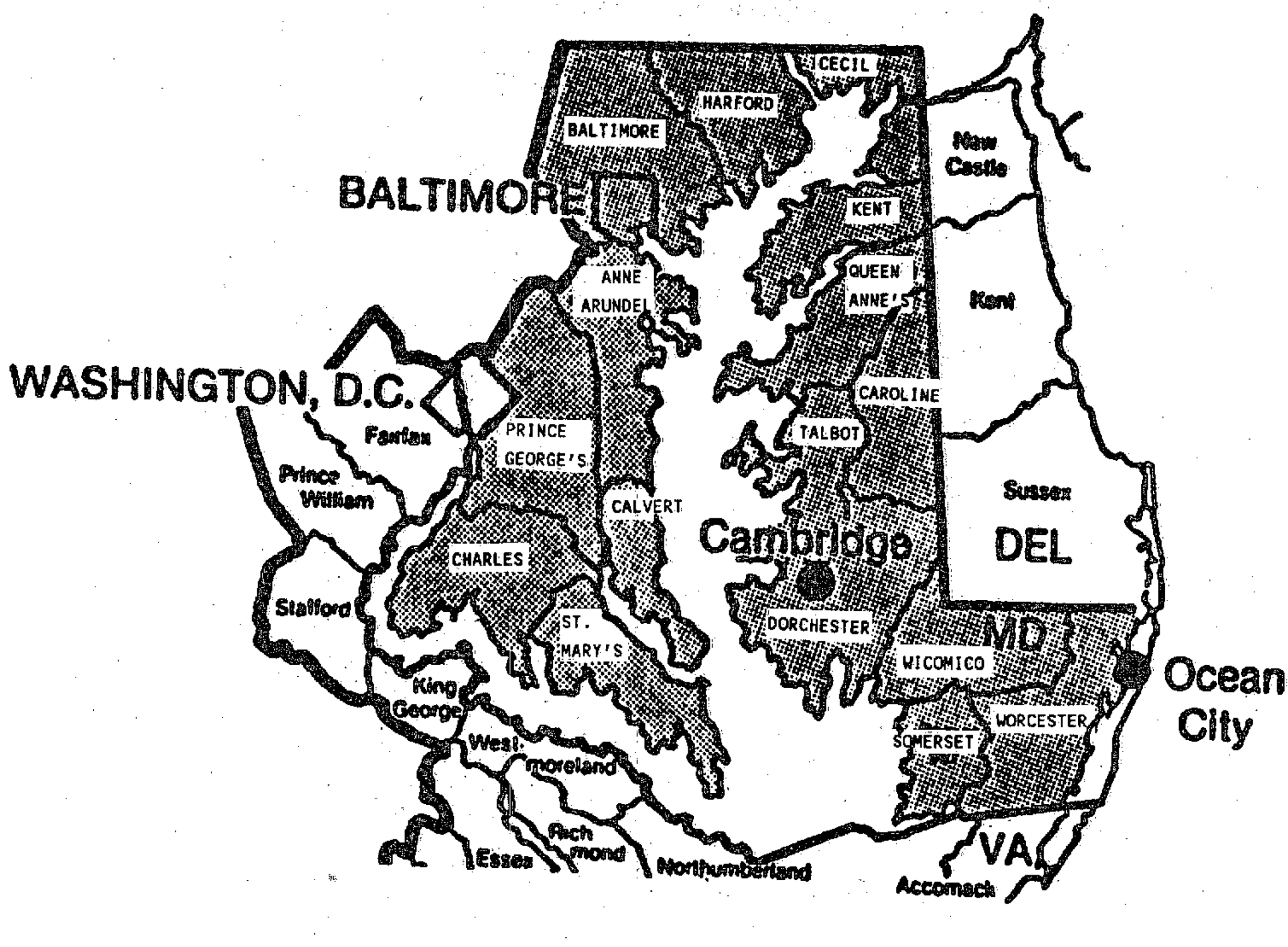
The study area covers a land area of approximately 6,500 square miles bordering the Chesapeake Bay, its tributaries, and the Atlantic Ocean. This comprises about 66 percent of the total land area in Maryland. The Bay shoreline contains many tidal bays, rivers, and inlets having an estimated length of 4,429 miles. About 40 miles of shoreline borders the Atlantic Ocean, 9 miles of which is the heavily developed resort town of Ocean City. The Assateague Island National Seashore and the Sinepuxent Wildlife Management Area occupy the remaining 31 miles of the coastline.

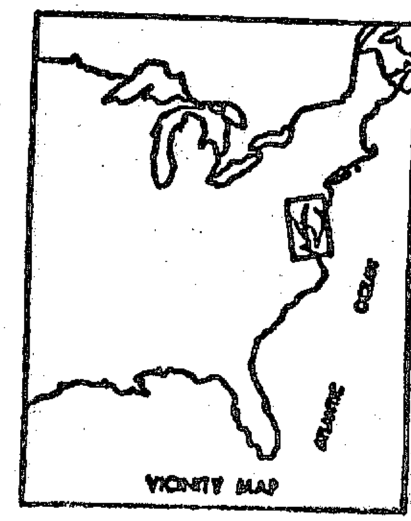
b. Topography. Physiographically, the study area is located primarily in the Atlantic Coastal Plain Province, although the northern and western portions are located in the Piedmont Region of the Older Appalachians Province. The two regions are separated by a fall line where elevations and characteristics change rapidly. The Coastal Plain consists of sedimentary deposits eroded from the adjacent uplands. Elevations range from about 500 feet near the Fall Line to sea level in the lowlands and beaches adjacent to tidal waters. More than half of the Coastal Plain is below 100 feet in elevation. Major streams exhibit tidal influence up to the Fall Line.

c. Bathymetry. Because shallow water close to shore tends to increase the magnitude of hurricane-induced storm surge, the bathymetry of the study area is crucial. Only forty miles of the Maryland shoreline, a small percentage, borders the Atlantic Ocean. The 10-fathom (-60 feet mean sea level) contour lies about 12 statute miles offshore from Assateague. The slope between the 10 and 100-fathom contours is relatively flat compared

FIGURE 1-1

STUDY AREA





with other areas in the mid-Atlantic region. The 100-fathom (-600 feet mean sea level) contour lies more than 200 statute miles offshore.

Most of Maryland's shoreline borders the Chesapeake Bay estuary, which is the drowned river valley of the Susquehanna River. The main bay extends approximately 190 miles north from the ocean entrance in the Commonwealth of Virginia, between Cape Henry and Cape Charles, to the mouth of the Susquehanna River in the State of Maryland. The average depth of the bay is about 28 feet, although a natural channel with depths greater than 50 feet traverse the bay for more than 60 percent of its length. The maximum depth of 175 feet is located in the upper bay near Bloody Point, Kent Island, Maryland.

Like many coastal plain estuaries, the bay is irregular in shape varying in width from 4 miles, between Annapolis and Kent Island, to 30 miles, in the middle bay off the Potomac River. Tides are mixed semidiurnal showing progressive wave characteristics at the ocean entrance and standing wave characteristics at the heads of the bay and tributaries. Tidal amplitudes and associated tidal currents are relatively low, generally under 1.5 feet and below 3 feet per second, respectively.

d. Population. The population of the study area was just over 3 million persons in the year 1980. This figure includes 73 percent of the total State of Maryland population. Table 1-1 lists the total population for each of the study area counties for the years 1960, 1970, 1980, 1985, and 1989. The percentage of change, which is also shown, illustrates a rapid rate of growth during the 1960's. Overall, the growth rate for the study area is comparable to that of the entire United States for the 25 year period between 1960 and 1985.

Historical Hurricane Activity

a. General. Hurricanes are a classification of tropical cyclones which are defined by the National Weather Service as nonfrontal, low pressure, large scale systems that develop over tropical or subtropical waters and have a definite organized circulation. The classification of tropical cyclones into tropical depressions, tropical storms, or hurricanes depends upon the speed of the sustained (1-minute average) surface winds near the center of the system and are defined as follows:

tropical depression:	less than or equal to 33 knots (38 mph),
tropical storm:	34 to 63 knots (39 to 73 mph) inclusive,
hurricane:	greater than or equal to 63 (73 mph) knots.

The geographical areas affected by tropical cyclones are referred to as tropical cyclone basins. The Atlantic tropical cyclone basin is one of six in the world and includes much of the North Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico. The official Atlantic hurricane season begins on June 1 and extends through November 30 of each year; however, occasional tropical cyclones occur outside of this season. Early season tropical cyclones are almost exclusively confined to the western Caribbean and the Gulf of Mexico. However, by the end of June or early July, the area of formation gradually shifts eastward with a slight decline in the overall frequency of storms. By late July the frequency gradually increases, and the area of formation shifts still farther eastward.

By late August tropical cyclones form over a broad area which extends eastward to a region near the Cape Verde Islands off the coast of Africa. The period from about August 20 through September 15 encompasses the maximum number of the Cape Verde type storms, many of which travel across the entire Atlantic Ocean. After mid-September the frequency

TABLE 1-1

TOTAL POPULATION AND CHANGES
IN STUDY AREA COUNTIES

NAME OF COUNTY	POPULATION 1960 CENSUS	POPULATION 1970 CENSUS	PERCENT CHANGE 1960-70	POPULATION 1980 CENSUS	PERCENT CHANGE 1970-80	POPULATION 1985 PROJECTION	PERCENT CHANGE 1980-85	POPULATION 1989 PROJECTION	PERCENT CHANGE 1980-89
Anne Arundel	206,630	298,040	44.2	370,780	24.4	396,400	6.9	423,470	14.2
Baltimore City	939,020	905,790	-3.5	786,740	-13.1	756,050	-3.9	745,760	-5.2
Baltimore County	492,430	620,410	26.0	655,620	5.7	665,550	1.5	684,920	4.5
Calvert	15,830	20,680	30.6	34,640	67.5	41,050	18.5	47,880	38.2
Caroline	19,460	19,780	1.6	23,140	17.0	23,900	3.3	24,540	6.1
Cecil	48,410	53,290	10.1	60,430	13.4	65,550	8.5	69,560	15.1
Charles	32,570	47,680	46.4	72,750	52.6	84,800	16.6	98,170	34.9
Dorchester	29,670	29,410	-0.9	30,620	4.1	29,900	-2.4	30,070	-1.8
Harford	76,720	115,380	50.4	145,930	26.5	152,800	4.7	165,160	13.2
Kent	15,480	16,150	4.3	16,700	3.4	16,810	0.7	16,970	1.6
Prince George's	357,400	661,720	85.1	665,070	0.5	675,250	1.5	704,760	6.0
Queen Anne's	16,570	18,420	11.2	25,510	38.5	28,500	11.7	32,570	27.7
St. Mary's	38,920	47,390	21.8	59,900	26.4	65,300	9.0	71,070	18.6
Somerset	19,620	18,920	-3.6	19,190	1.4	19,050	-0.7	21,700	13.1
Talbot	21,580	23,680	9.7	25,600	8.1	26,950	5.3	28,580	11.6
Wicomico	49,050	54,240	10.6	64,540	19.0	67,800	5.1	72,460	12.3
Worcester	23,730	24,440	3.0	30,890	26.4	34,700	12.3	37,740	22.2
TOTAL	2,403,090	2,975,420	23.8	3,088,050	3.8	3,150,360	2.0	3,275,380	6.1
U.S. (MILLIONS)	179.3	205.1	14.4	227.8	11.1	239.3	5.0	--	--

GROWTH IN U.S. 1960-1985............. 33.5 PERCENT

GROWTH IN AREA 1960-1985............. 31.1 PERCENT begins to decline and the formative area retreats westward. By early October the area of maximum occurrence returns to the western Caribbean. In November the frequency of tropical cyclone occurrence further declines.

b. Atlantic Tropical Cyclone Basin. Through the research efforts of the National Climate Center, in cooperation with the National Hurricane Center, records of tropical cyclone occurrences within the Atlantic tropical cyclone basin have been compiled dating back to 1871. Although other researchers have compiled fragmentary data concerning tropical cyclones within the Atlantic tropical cyclone basin back to the late fifteenth century, the years from 1871 to the present represent the complete period of the development of meteorology and organized weather services in the United States.

For the 115-year period 1871 through 1985, a total of 928 tropical cyclones have occurred within the Atlantic tropical cyclone basin. However, for the years 1871 through 1885, the existing data do not allow accurate determinations of the intensities of the tropical cyclones occurring during those years. The National Hurricane Center maintains detailed computer files of the Atlantic tropical cyclone tracks back to 1886. Of the 839 known Atlantic tropical cyclones of at least tropical storm intensity occurring during the period 1886 through 1985, 492 are known to have reached hurricane intensity.

c. Maryland Hurricane Study Area. Between 1886 and 1985, 18 tropical cyclones of hurricane intensity passed within 100 statute miles of Wallops Island, Virginia for an average of one hurricane within the 100 mile circle every 5.6 years. Table 1-2 lists the tropical cyclones which have passed within 100 statute miles of Wallops Island between the years of 1886 and 1985, and Figure 1-2 shows the tracks of these storms.

Major Analyses

The Maryland Hurricane Evacuation Study consists of several related analyses that develop technical data concerning hurricane hazards, vulnerability of the population, public response to evacuation advisories, timing of evacuations, and sheltering needs for various hurricane threat situations. The major analyses comprising the Maryland Hurricane Evacuation Study and a description of the methodologies for each are as follows:

a. Hazards Analysis. (Chapter 2) The hazards analysis determines the timing, severity, and sequence of wind and hurricane surge hazards that can be expected from hurricanes of various categories, tracks, and forward speeds striking the study area. The Sea, Lake, and Overland Surges from Hurricanes (SLOSH) numerical model was used to develop the data. Freshwater flooding from rainfall from hurricanes was generally addressed by identifying areas within each of the counties which might be inaccessible due to flooding from rainfall, particularly those areas which might be considered for shelter facilities or evacuation routes.

b. Vulnerability Analysis. (Chapter 3) Utilizing the results of the hazards analysis, the vulnerability analysis identifies those areas, populations, and facilities that are vulnerable to specific hazards under a variety of hurricane threats. Using major natural or man-made geographic features for delineation purposes, evacuation zones were developed for each of the study area counties. Groups of evacuation zones, called hurricane evacuation scenarios, that will be threatened by storm surge from specific hurricane intensity categories were also developed for each county. Projected 1989 population data were used in determining the vulnerable population within each county for a range of hurricane threats.

TABLE 1-2

TROPICAL CYCLONES WITHIN 100 STATUTE MILES OF WALLOPS ISLAND 1886 TO 1985

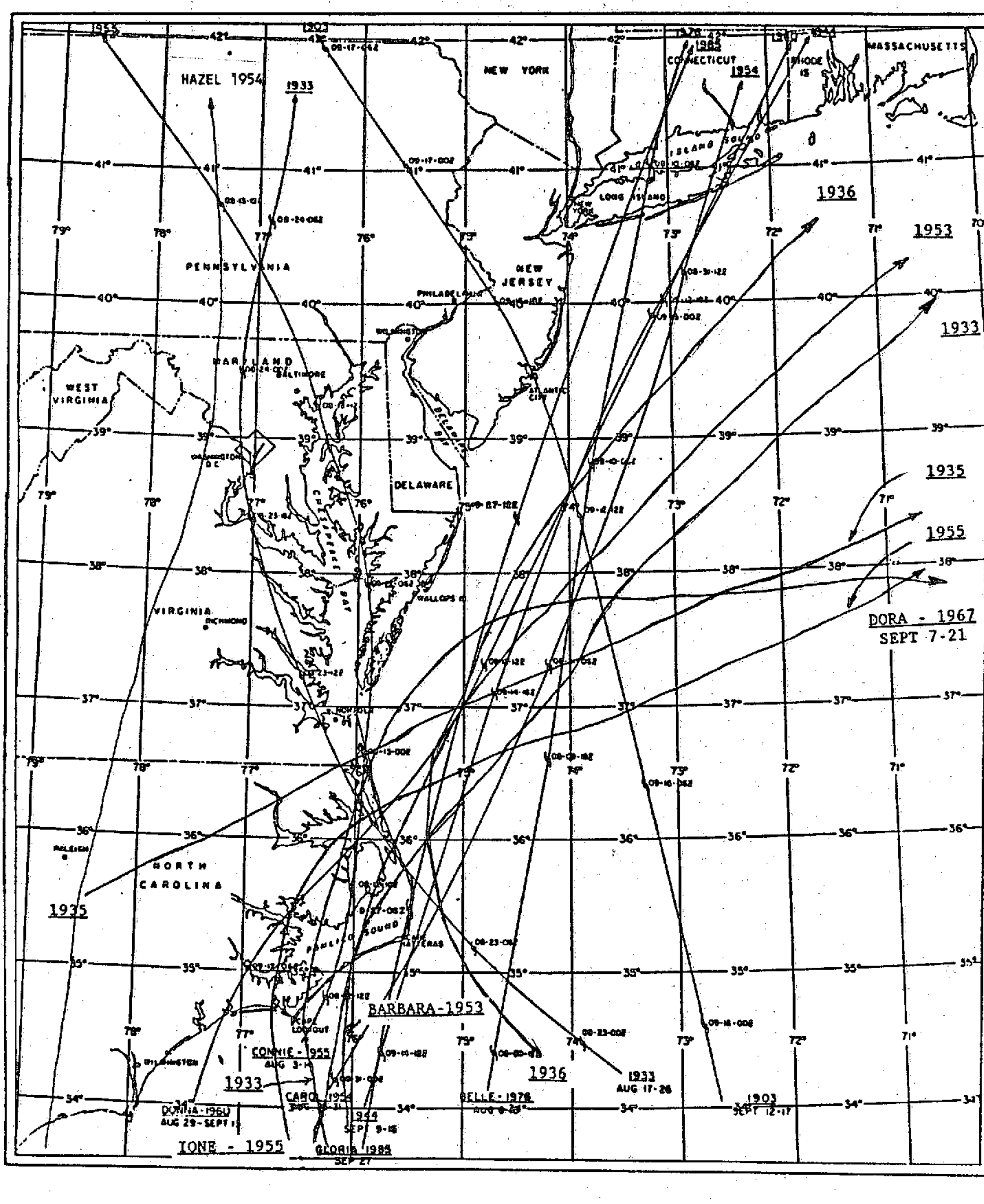
DATE OF STORM	STORM NAME	RANGE (MILES TO CPA)	MAXIMUM SUSTAINED WIND SPEED (mph)	STORM FORWARD SPEED (mph)	STORM DIRECTION
1893 Aug 24	Unnamed	81	98	24	N
1894 Sep 29	Unnamed	56	81	7	NE
1894 Oct 10	Unnamed	15	75	27	NNE
1899 Aug 19	Unnamed	82	90	8	NE
1903 Sep 16	Unnamed	93	84	24	NNW
1933 Aug 23	Unnamed	74	104	18	NNW
1933 Sep 16	Unnamed	83	86	19	NE
1935 Sep 6	Unnamed	62	78	32	ENE
1936 Sep 18	Unnamed	41	98	19	NNE
1944 Sep 14	Unnamed	58	99	35	NNE
1953 Aug 14	Barbara	56	81	17	NE
1954 Aug 31	Carol	79	98	38	NNE
* 1954 Oct 15	Hazel	135	92	49	N
1955 Aug 13	Connie	23	98	15	NNW
1955 Sep 20	Ione	93	79	9	ENE
1960 Sep 12	Donna	53	109	34	NNE
1967 Sep 16	Doria	33	77	9	SW
1976 Aug 9	Belle	82	101	26	N
1985 Sep 27	Gloria	30	104	30	NNE

NOTE: CPA = Closest Point of Approach

* Although Hazel did not pass within 100 miles of Wallops Island, it was a very destructive storm which passed within 100 miles of many locations in the study area.

FIGURE 1-2

HISTORICAL HURRICANE TRACKS



c. Behavioral Analysis. (Chapter 4) This analysis determines the expected response of the threatened population to various hurricane threats in terms of the percentage of the population expected to evacuate, probable destinations of evacuees, use of public shelters, and utilization of available vehicles. The tools employed in the Maryland Hurricane Evacuation Study to develop the behavioral data consisted of telephone sample surveys and personal interviews within the study area, data from other hurricane evacuation studies, and data from post-hurricane evacuation studies.

d. Shelter Analysis. (Chapter 5) The shelter analysis presents an inventory of existing public shelter facilities and their capacities, and identifies the range of potential shelter demand for each county. Inventories of existing shelters and capacities were furnished by the appropriate local officials or American Red Cross representatives responsible for shelters in each county. Potential shelter demands for the range of hurricane threats were developed using data from the behavioral analysis.

e. Transportation Analysis. (Chapter 6) The purpose of this analysis is to determine the time required to evacuate the threatened population under a variety of hurricane threats. Transportation modeling techniques developed to simulate hurricane evacuation traffic patterns were used to conduct this analysis. The results of all previous analyses were utilized in the transportation analysis. In addition, the results of the transportation analysis of the Delaware Hurricane Evacuation Study, which was conducted concurrently with the Maryland Study, were used to determine the Maryland hurricane traffic characteristics.

Due to higher elevations, the vulnerable areas of the Western Shore counties were generally smaller than those of the Eastern Shore counties. It was postulated that smaller vulnerable areas would correspond to fewer evacuating people and vehicles and that the resulting evacuation clearance times would be solely dependent upon assumed response curves, which are discussed in Chapter Four. A complete transportation analysis of two Western Shore counties, Anne Arundel and St. Mary's, indicated that this assumption was correct. Thus, for the remaining Western Shore counties (Baltimore, Calvert, Charles, Cecil, Harford, Prince George's, and Baltimore City), no transportation analysis was performed. Instead, clearance times are assumed to be equal to expected response time. Consequently, throughout the remainder of this document, data which corresponds to the transportation analysis is presented only for the Eastern Shore counties.

Coordination

A coordination program was established for the Maryland Hurricane Evacuation Study that included State and local emergency management officials and representatives from other organizations having direct responsibilities in hurricane emergencies. Due to the diversity and number of counties represented in the study, no formal committee was formed. Instead, direct coordination was established among the Maryland Emergency Management Agency, the Corps of Engineers, and the Local Directors of the appropriate emergency management agencies. The Maryland Department of Natural Resources was included in the administrative oversight of the study and received issues of the quarterly status report. Officials from the Maryland Emergency Management Agency, Corps of Engineers, and Federal Emergency Management Agency served as members of the Executive Committee. This committee convened as needed to review the progress of the study, to discuss and plan for future study tasks, and to assure proper and thorough data gathering and coordination of the study.

CHAPTER TWO

HAZARDS ANALYSIS

Purpose

The purpose of the hazards analysis is to quantify the still-water surge heights, waves, and wind speeds for various intensities and tracks of hurricanes considered to have a reasonable meteorological probability of occurring within a particular coastal basin. Potential freshwater flooding from rainfall accompanying hurricanes is also addressed; however, due to the wide variation in amounts and times of occurrence from one storm event to another, rainfall can only be addressed in general terms.

The results of the hazards analysis determine the probable worst-case effects from various intensity hurricanes that could strike the region. For the purposes of this study, the term worst-case is used to describe the peak surges, wind speeds, wave effects, and potential rainfall that can be expected at all locations within the study area regardless of the point of the hurricane's eye landfall.

Forecasting Inaccuracies

Due to the inaccuracies in forecasting the precise tracks and other parameters of approaching hurricanes, worst-case effects are determined for the hazards analysis. An analysis of hurricane forecasts made by the National Hurricane Center indicates the magnitude of error that can be expected. From 1976 to 1985, the average error in the official 24-hour hurricane track forecast was 140 statute miles left or right of the forecast track. The average error in the 12-hour official forecast was 69 miles. During the same time period, the average error in the official 24-hour wind speed forecast was 15 miles per hour (m.p.h.) and the average error in the 12-hour official forecast was 10 m.p.h.

Hurricane evacuation decision-makers should note that an increase of 10 to 15 m.p.h. can raise the intensity category of the approaching hurricane one category on the Saffir/Simpson Hurricane Scale (see Table 2-1). Also, other factors may work to increase apparent hurricane surge heights above the predicted heights. Because of these forecast inaccuracies, the National Hurricane Center and Maryland Emergency Management Agency recommend that public officials faced with an imminent evacuation prepare for the evacuation operation as if the approaching hurricane will intensify one category on the Saffir/Simpson Hurricane Scale above the strength forecast for landfall.

Potential Storm Surge

a. General. A hurricane moving over the continental shelf produces a buildup of water at the coastline that is commonly referred to as storm surge or hurricane surge. Storm surge is the increase in height of the surface of the sea due to the forces of an approaching hurricane. Along the mid-Atlantic seaboard, hurricanes have the potential to produce surges which are 15 to 20 feet above normal sea surface levels. Storm surge is often the most dangerous threat from a hurricane and has great potential for property damage and loss of life.

Storm surge normally occurs over coastline distances of 100 miles or more. The winds associated with a hurricane are the primary cause of storm surge within a basin. Wind blowing over the surface of the water exerts a horizontal force that induces a surface current in the general direction of the wind. The surface current, in turn, induces currents in subsurface water. This process of current creation continues to a depth determined by the intensity and forward motion of the hurricane. For example, a fast moving hurricane of moderate intensity may only induce currents to a depth of a hundred feet, whereas a slow moving hurricane of the same intensity might induce currents to several hundred feet. As the hurricane approaches the coastline, these horizontal currents are impeded by a sloping continental shelf, thereby causing the water level to rise. The amount of rise increases shoreward to a maximum level at the normal coastline, or possibly further inland.

The height of the storm surge within a coastal basin depends upon the meteorological parameters of the hurricane as well as the physical characteristics existing within the basin. The meteorological parameters affecting the height of the surge include the intensity of the hurricane, measured by the storm-center sea-level pressure; the path or track of the storm; forward speed; and radius of maximum winds.

The physical characteristics of a basin that influence the surge heights include the basin bathymetry, roughness of the continental shelf, configuration of the coastline, and natural or manmade barriers. Another factor that affects the storm surge height is the initial water level within the basin at the time the hurricane strikes, including the astronomical tide and any anomalous sea surface height.

Generally, the highest surges from a hurricane occur in the region of the radius of maximum winds and to the right of the hurricane's forward track. This is extremely important when the storm makes landfall because the maximum storm surge may vary significantly within a relatively short distance, depending on whether the hurricane lands to the right or left of a given location. This radius is measured from the center of the hurricane eye to the location of the highest wind speeds within the storm. The radius of maximum winds can vary from as little as 4 miles to as much as 50 miles.

b. <u>Background</u>. Numerous methods and models have been utilized to quantify the potential storm surge generated by hurricanes. One of the earlier guides developed for that purpose is the Saffir/Simpson Hurricane Scale. It was developed by Herbert Saffir, Dade County, Florida, Consulting Engineer, and Dr. Robert H. Simpson, former Director of the National Hurricane Center. The Saffir/Simpson Hurricane Scale, presented in Table 2-1, is a descriptive scale which categorizes hurricanes based upon intensity and relates hurricane intensity to damage potential. The Saffir/Simpson Hurricane Scale also provides a range of wind speeds and potential surge heights associated with the five categories of hurricanes.

The National Hurricane Center has added a range of central barometric pressures associated with each category of hurricane described by the Saffir/Simpson Hurricane Scale. A condensed version of the Saffir/Simpson Hurricane Scale with the barometric pressure ranges is shown in Table 2-2.

The Saffir/Simpson Hurricane Scale assumes an average, uniform coastline for the continental Unites States and was intended as a general guide for use by public safety officials during hurricane emergencies. It does not reflect the effects of varying localized bathymetry, coastline configuration, barriers, or other factors that can greatly influence the surge heights that occur at different locations during a single hurricane event.

Expanding upon the Saffir/Simpson categorization, the National Weather Service developed computer models for specific coastal basins that account for bathymetry and other variables that affect surge heights. One of the most notable of these mathematical models is the Special Program to List the Amplitude of Surges from Hurricanes (SPLASH) model. Two versions of this model, SPLASH I and SPLASH II, were developed for selected basins along the Gulf and Atlantic coasts. Although the SPLASH model provides

TABLE 2-1

SAFFIR/SIMPSON HURRICANE SCALE

<u>CATEGORY 1.</u> Winds of 74 to 95 miles per hour. Damage primarily to shrubbery, trees, foliage, and unanchored mobile homes. No real wind damage to other structures. Some damage to poorly constructed signs. Storm surge possibly 4 to 5 feet above normal. Low-lying coastal roads inundated, minor pier damage, some small craft in exposed anchorages torn from moorings.

<u>CATEGORY 2.</u> Winds of 96 to 110 miles per hour. Considerable damage to shrubbery and tree foliage; some trees blown down. Major damage to exposed mobile homes. Extensive damage to poorly constructed signs. Some damage to roofing materials of building; some window and door damage. No major wind damage to buildings. Storm surge possibly 6 to 8 feet above normal. Coastal roads and low-lying escape routes inland cut by rising water 2 to 4 hours before arrival of hurricane center. Considerable damage to piers. Marinas flooded. Small craft in unprotected anchorages torn from moorings. Evacuation of some shoreline residences and low-lying island areas required.

<u>CATEGORY 3.</u> Winds of 111 to 130 miles per hour. Foliage torn from trees; large trees blow down. Practically all poorly constructed signs blown down. Some damage to roofing materials of buildings; some window and door damage. Some structural damage to small buildings. Mobile homes destroyed. Storm surge possibly 9 to 12 feet above normal. Serious flooding at coast and many smaller structures near coast destroyed; larger structures near coast damaged by battering waves and floating debris. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives.

<u>CATEGORY 4.</u> Winds of 131 to 155 miles per hour. Shrubs and trees blown down; all signs down. Extensive damage to roofings materials, windows, and doors. Complete failure of roofs on many small residences. Complete destruction of mobile homes. Storm surge possibly 13 to 18 feet above normal. Major damage to lower floors of structures near shore due to flooding and battering by waves and floating debris. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Major erosion of beaches.

<u>CATEGORY 5.</u> Winds greater than 155 miles per hour. Shrubs and trees blown down; considerable damage to roofs of buildings; all signs down. Very severe and extensive damage to windows and doors. Complete failure of roofs on many residences and industrial buildings. Some complete building failures. Small buildings overturned or blown away. Complete destruction of mobile homes and to lower floors of all structures less than 15 feet above sea level. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives.

TABLE 2-2

SAFFIR/SIMPSON HURRICANE SCALE
WITH
CENTRAL BAROMETRIC PRESSURE RANGES

CATEGORY	CENTRAL PRESSURE (MILLIBARS)	(INCHES)	WINDS (MPH)	SURGE (FT)	DAMAGE
1	>980	>28.94	74-95	4-5	Minimal
2	965-979	28.50-28.91	96-110	6-8	Moderate
3	945-964	27.91-28.47	111-130	9-12	Extensive
4	920-944	27.17-27.88	131-155	13-18	Extreme
5	<920	<27.17	>155	>18	Catastrophic

reliable still-water storm surge heights, it is rather limited in that the surge heights are calculated only for open coastlines. The latest mathematical model developed by the National Weather Service, the Sea, Lake and Overland Surges from Hurricanes (SLOSH) model, is an expansion of the SPLASH model that has the capability of calculating storm surge heights within coastal sounds and estuaries. Information contained in the outputs of the two models is basically the same. The SLOSH model was used exclusively for the Maryland Hurricane Evacuation Study hazards analysis.

c. The SLOSH Model.

(1) General. The Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model is the latest and most sophisticated mathematical model yet developed by the National Weather Service to calculate potential surge heights from hurricanes. The SLOSH model was developed for real-time forecasting of surges from actual hurricanes within selected Gulf and Atlantic coastal basins. In addition to furnishing surge heights for the open coast, the SLOSH model has the capability to simulate the routing of storm surge into sounds, bays, estuaries, and coastal river basins, as well as the capacity to calculate surge heights for overland locations. Significant natural and manmade barriers are represented in the model, and their effects are simulated in the calculations of surge heights within a basin.

The SLOSH model is designed for use in an operational mode; that is, for forecast/hindcast runs without controlled, local calibration, or observed winds. The rationale for this design is to avoid having the user predict unavailable input data. The SLOSH model contains a storm model into which simple time-dependent meteorological data are input and from which the driving forces of a simulated storm are calculated. These data include the following:

(a) Latitude and longitude of storm positions at 6-hour intervals for a 72-hour period.

(b) Central barometric pressure at 6-hour intervals for a 72-hour period.

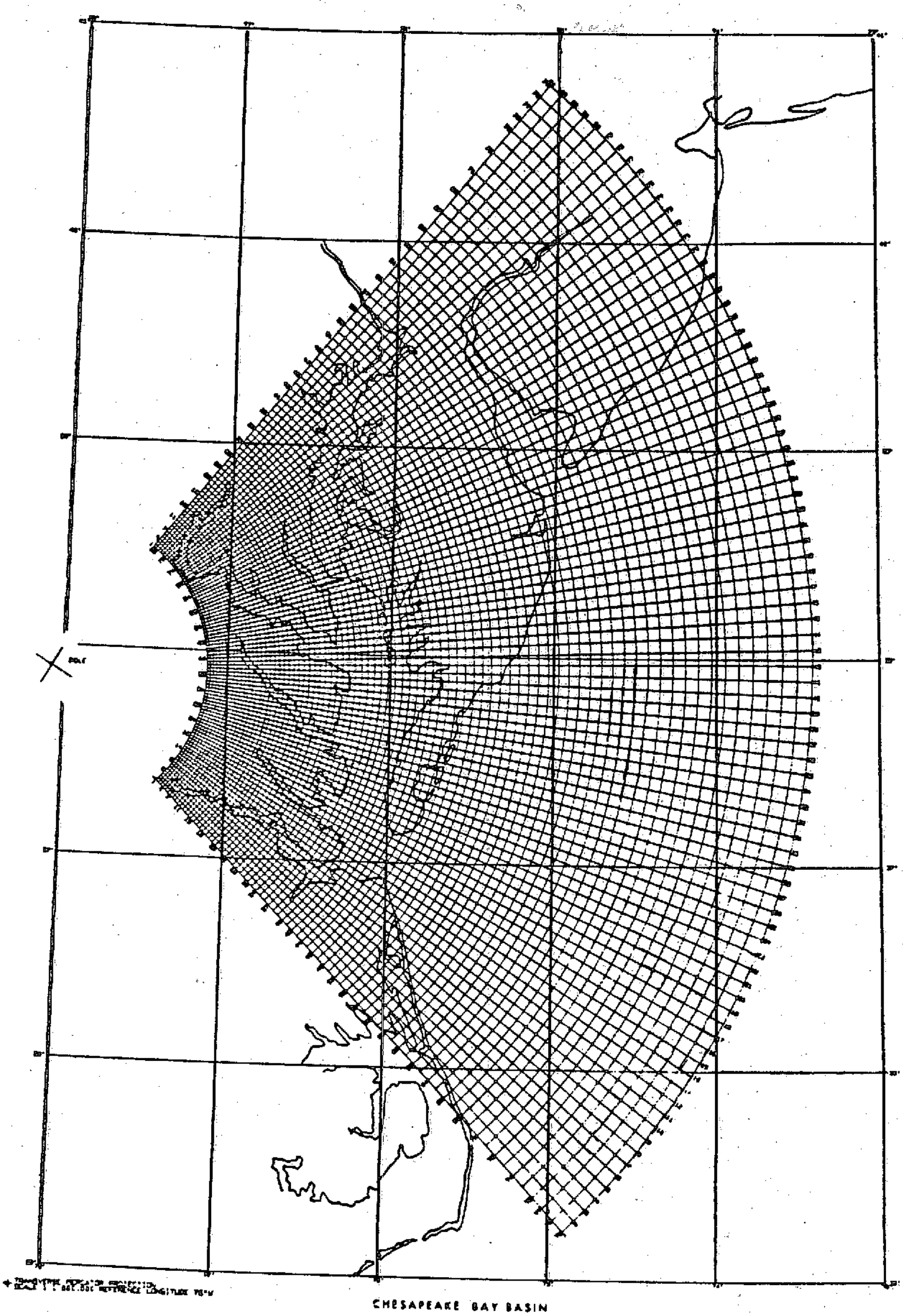
(c) The storm size measured from the center (eye) of the storm to the region of maximum winds; commonly referred to as the radius of maximum winds.

The windspeeds in the hurricane are not input by the modeler. Instead, the SLOSH model calculates the radial surface wind profile, or windfield, from the other meteorological input parameters. In addition, the initial height of the water surface well before the storm directly affects the area of interest and is a required input parameter. This initial height is the observed, quiescent, water surface height occurring about two days before storm arrival and includes any existing anomalous rise in the water surface. Astronomical tide is not set in the model but can be added to the computed surge heights. The omission of astronomical tide from the model prevents the generation of any error in predicting the tide's phasing with the storm track.

(2) SLOSH Grid Configuration. The SLOSH model utilizes a telescoping polar coordinate (fan-shaped) grid system to represent a particular coastal basin. The grid configuration of the Chesapeake Bay area SLOSH model is illustrated in Figure 2-1. Storm surge heights at sea, distant from the open coast, are of secondary interest in

FIGURE 2-1

CHESAPEAKE BAY AREA SLOSH GRID



evacuation planning. In order to offer good resolution in areas of primary interest, the coastal and inland areas, while minimizing the number of calculations required to model a storm, the grid squares constantly expand in size and become progressively larger out from the coastline. The resolution of the model for inland locations near the focus is approximately 1 square mile per grid square and increases to approximately 42 square miles at the outer fringe.

The characteristics of a particular basin are constructed as input data within the model. These characteristics include the topography of inland areas; river basins and waterways; bathymetry of nearshore areas, sounds, bays, and large inland water bodies; significant natural and manmade barriers such as barrier islands, dunes, roads, and levees; and a segment of the continental shelf. The SLOSH model simulates inland flooding from storm surge and permits the overtopping of barriers and flow through barrier gaps.

(3) Verification of the Model. After a SLOSH model has been constructed for a coastal basin, verification experiments are conducted. The available meteorological data from historical storms are input in the model. These input data consist solely of observed or hindcast storm parameters and an initial observed sea surface height occurring approximately 48 hours before the storm landfalls or affects the basin.

The computed surge heights are compared with those measured from historical storms and, if necessary, adjustments are made to the input or basin data. These adjustments are made to accurately represent the basin characteristics and historical storm parameters. In instances where the model has given realistic results in one area of a basin but not in another, closer examination of the basin often has revealed inaccuracies in the representation of barrier heights or missing values in bathymetric or topographic charts. In the case of historical storms, much of the data are often coarse, with parameters prescribed invariant with time and with an unrealistically smoothed storm track. When necessary, further analysis and subjective decisions are employed to amend the track or other parameters of the historical storms used in the verification process.

(4) Model Output. The standard data products from a given SLOSH model run consist of both graphical and tabulated information. The graphical data output by the model consists of a plot of the original telescoping polar coordinate grid in a rectilinear format. Each grid cell is plotted at a uniform size, which has the effect of distorting the apparent shape of the coastline and other physical features. Cells near the origin of the polar grid are thus expanded relative to their original size, while cells near the outer portion of the polar grid are contracted relative to their original size.

The rectilinear plot of the model basin for a given SLOSH simulation displays the following information:

i. The track of the hurricane being modeled.

ii. The locations and names of selected geographic points.

iii. The maximum water surface elevation attained at each grid cell over the duration of the storm being simulated. This plot does not represent a "snapshot" of the storm surge at an instant of time. Instead, it represents the highest water level at each grid point during a hurricane regardless of the actual time of occurrence during that storm. This plot of maximum surge heights is referred to as the "envelope" of maximum surge for a particular storm acting on a specific SLOSH modeled basin.

The tabulated output data consist of the following:

i. User input values of storm center latitude and longitude, radius of maximum winds, and central pressure differential.

ii. User input starting water surface elevation.

iii. Model interpolated values, at one hour intervals, of storm location (latitude and longitude), forward speed and track direction, central pressure differential, and radius of maximum winds.

iv. Model computed values, at one-half hour intervals, of surge height, wind speed, and wind direction at a number of sites selected by the user. The grid sites selected for this study coincide with critical locations identified by the Maryland Local Emergency Management Coordinators. They are located at low-lying roads and bridges that would be critical to an evacuation, at potentially vulnerable population centers, or at significant natural or manmade barriers.

d. Maryland - Chesapeake Bay Region Modeling Process.

(1) General. The Chesapeake Basin SLOSH model is the primary model used for the Maryland Hurricane Evacuation Study. The Chesapeake SLOSH Basin covers the Maryland coastline from the Virginia border, including all the Maryland counties surrounding the Chesapeake Bay.

(2) Simulated Hurricanes. A total of 389 hypothetical hurricanes were modeled for this study. The characteristics of the simulated hurricanes were determined from an analysis of historical hurricanes that have occurred within the study area. The parameters selected for the modeled storms were the intensities, forward speeds, approach directions, and radii of maximum winds that are considered to have the highest meteorologic probability of occurrence in the Chesapeake Basin.

A total of 67 storm tracks were modeled for the Maryland Hurricane Evacuation Study and are shown in Figures 2-2 through 2-7. The simulated hurricanes moving along these tracks had combinations of parameters representing four of the five categories of hurricane intensity, as described by the Saffir/Simpson Hurricane Scale. The National Hurricane Center determined that the fifth and most intense category of hurricane does not pose a threat to Maryland because it requires meteorological conditions which cannot be sustained at latitudes as far north as Maryland. Table 2-3 summarizes the combinations of storm parameters which were used in the SLOSH model of the Maryland study area.

Six approach directions for landfalling were considered. These included west-northwestbound, northwestbound, northbound, north-northwestbound, northeastbound and north-northeastbound. Many landfall or closest approach locations, generally spaced about 20 miles apart along the coastline, were considered with forward speeds ranging from 20 mph to 40 mph. The radius of maximum winds specified for the simulated hurricanes ranged from 30 miles to 40 miles.

After making landfall, most hurricanes weaken because the central pressure increases and the radius of maximum winds tends to increase. The hurricane intensities modeled for each of the storm tracks were those considered to be the most meteorologically probable. The expected effects of the landmass on hurricane intensity were taken into account during the modeling.

FIGURE 2-2

WEST-NORTHWESTWARD MOVING HURRICANES

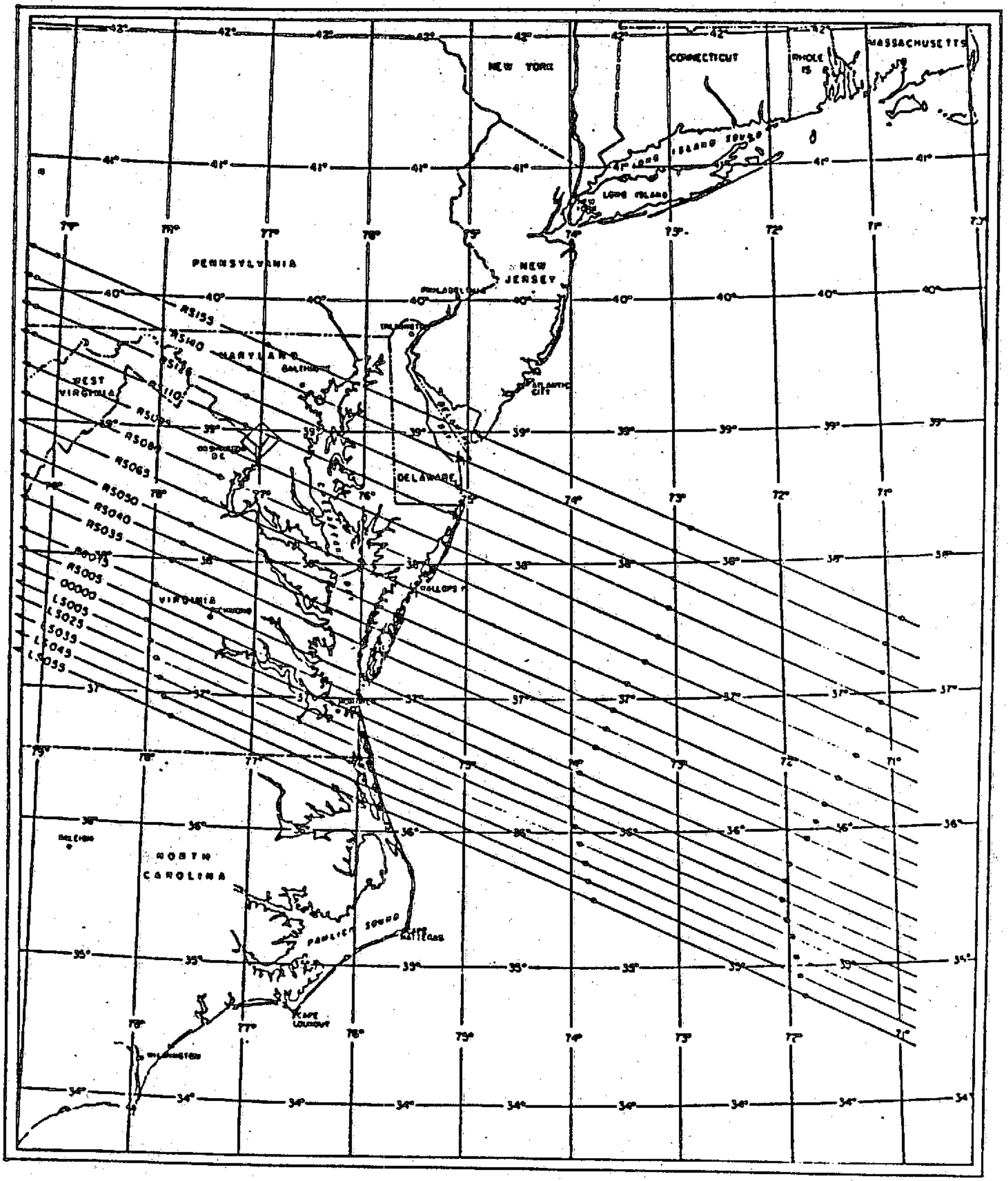


FIGURE 2-3

NORTHWESTWARD MOVING HURRICANES

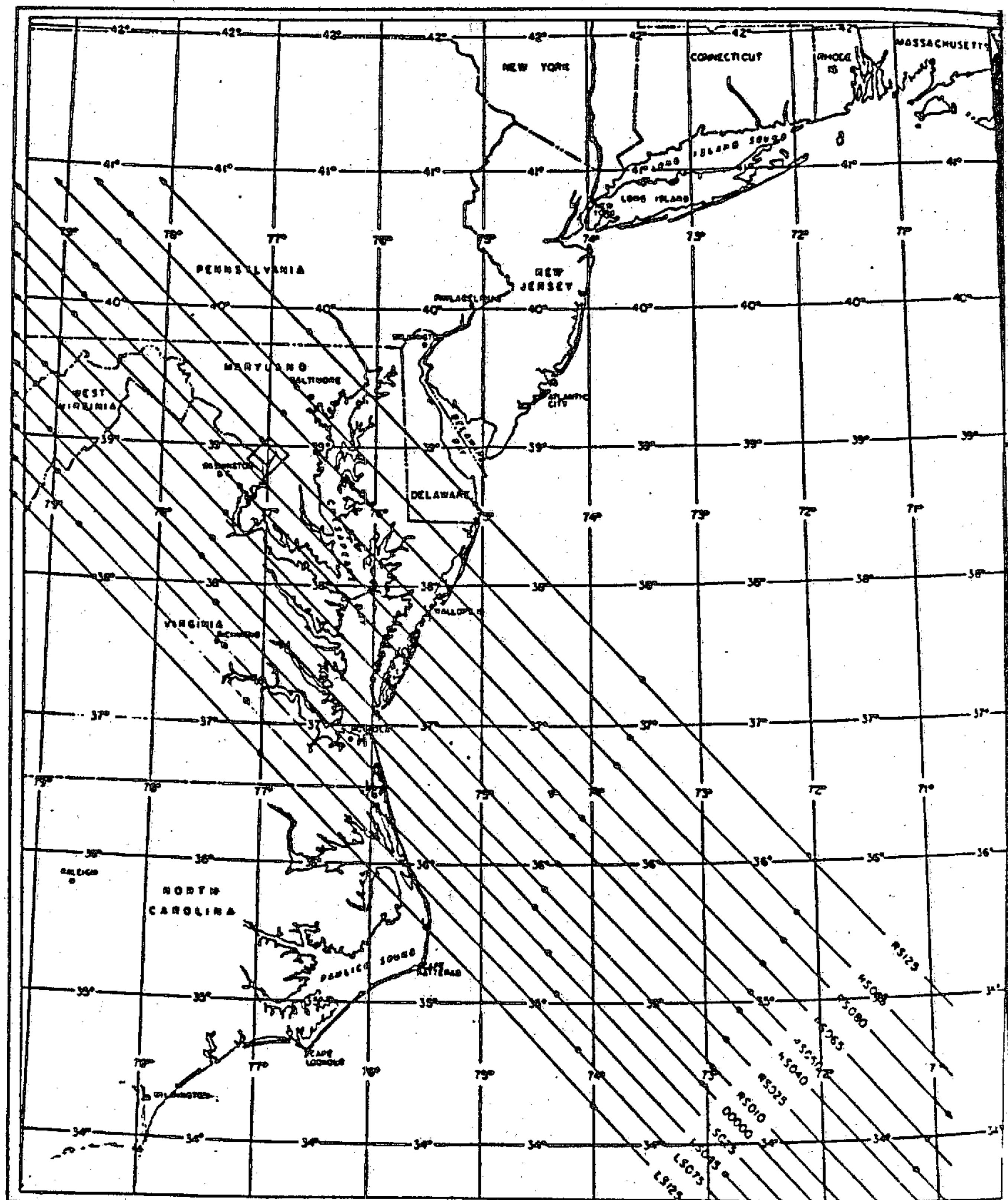


FIGURE 2-4

NORTHWARD MOVING HURRICANES

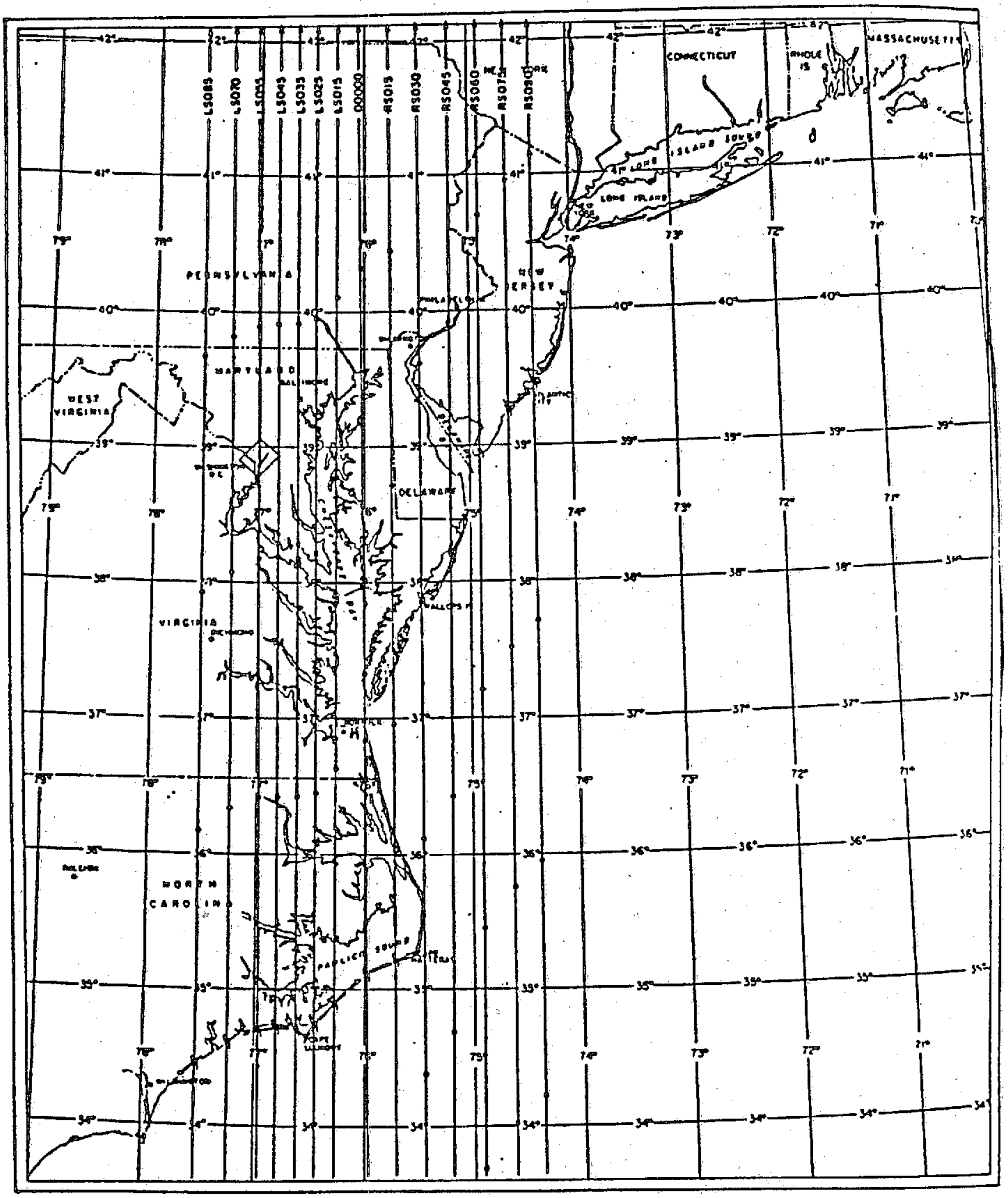


FIGURE 2-5

NORTH-NORTHWESTWARD MOVING HURRICANES

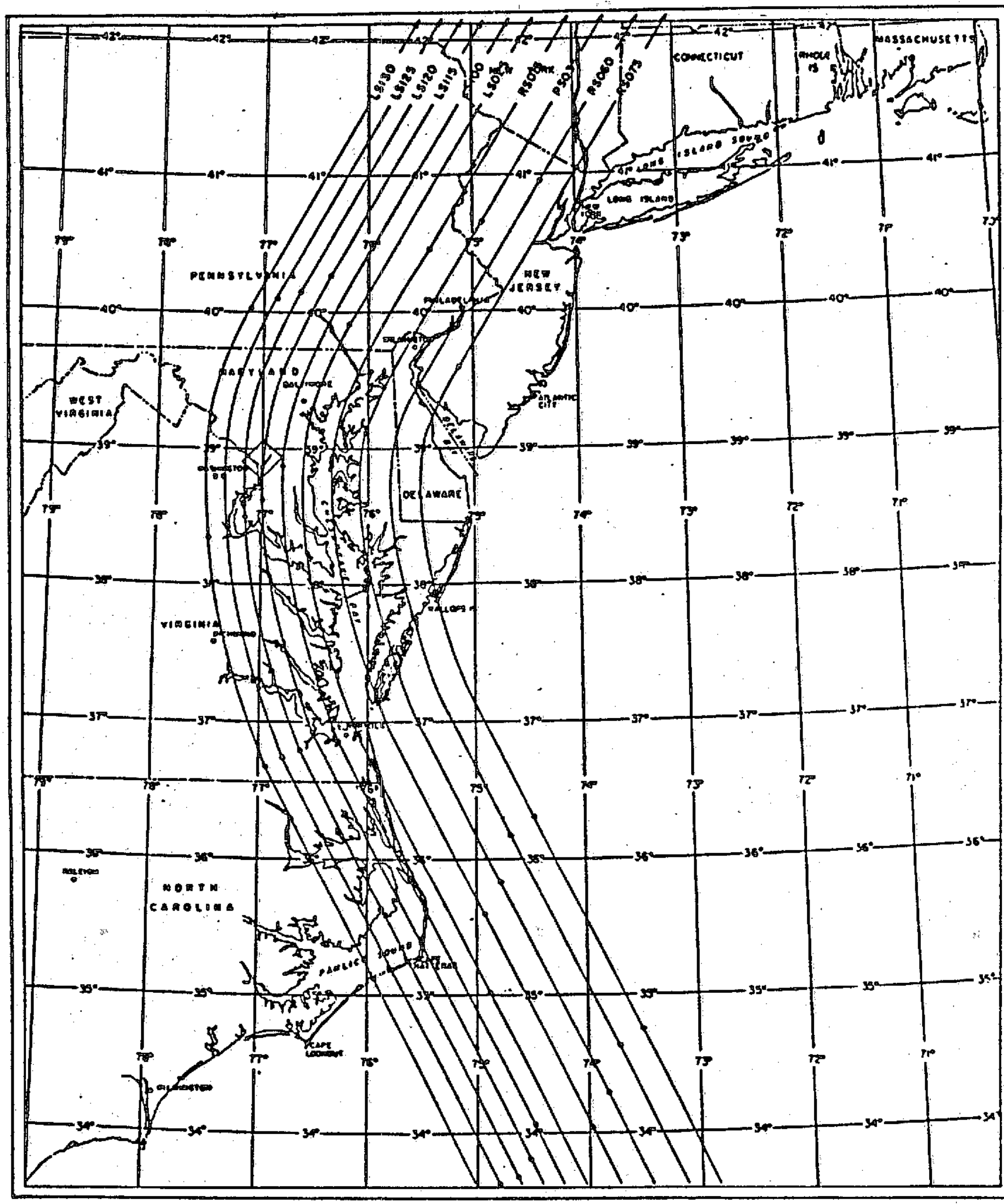


FIGURE 2-6

NORTHEASTWARD MOVING HURRICANES

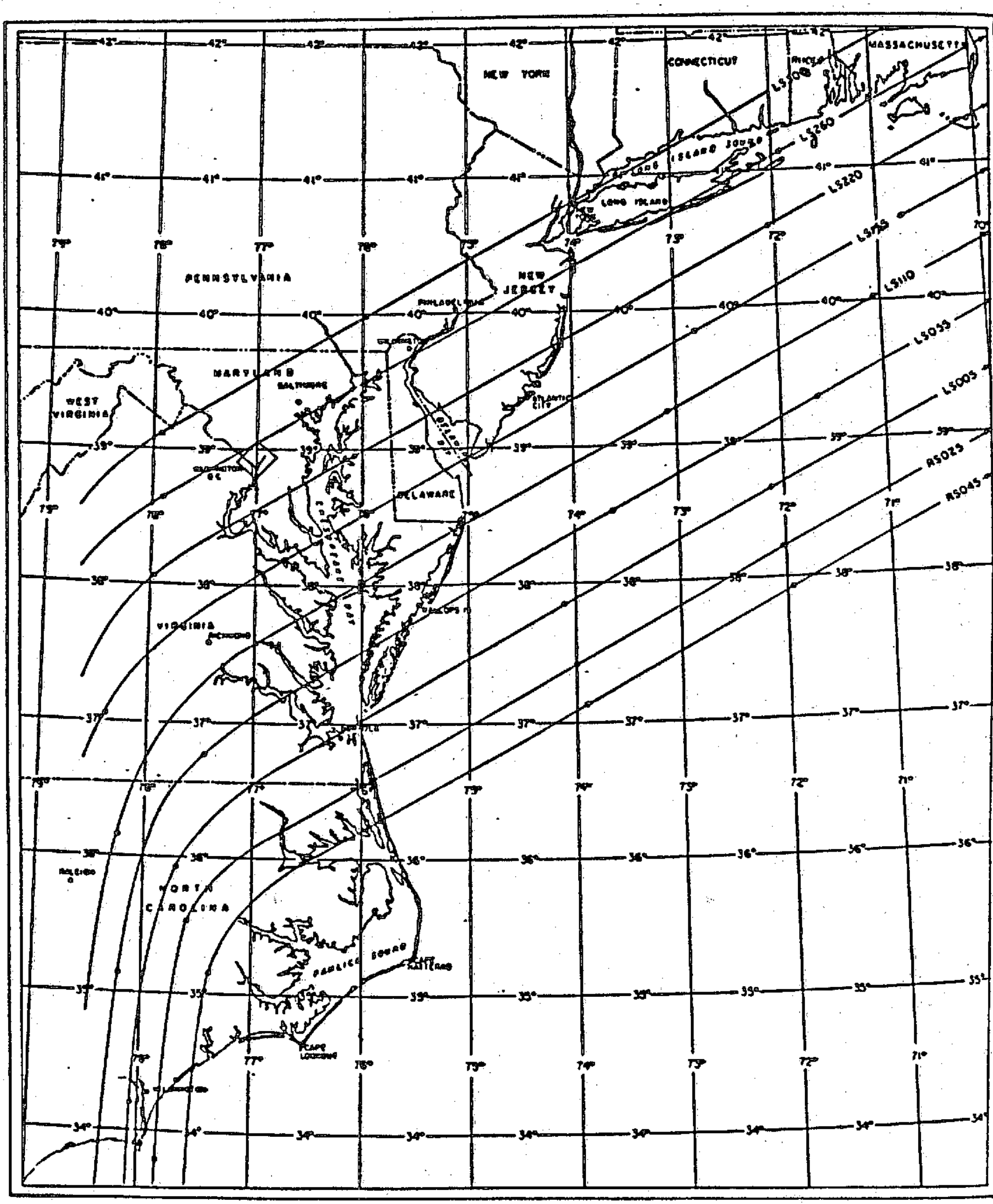


FIGURE 2-7

NORTH-NORTHEASTWARD MOVING HURRICANES

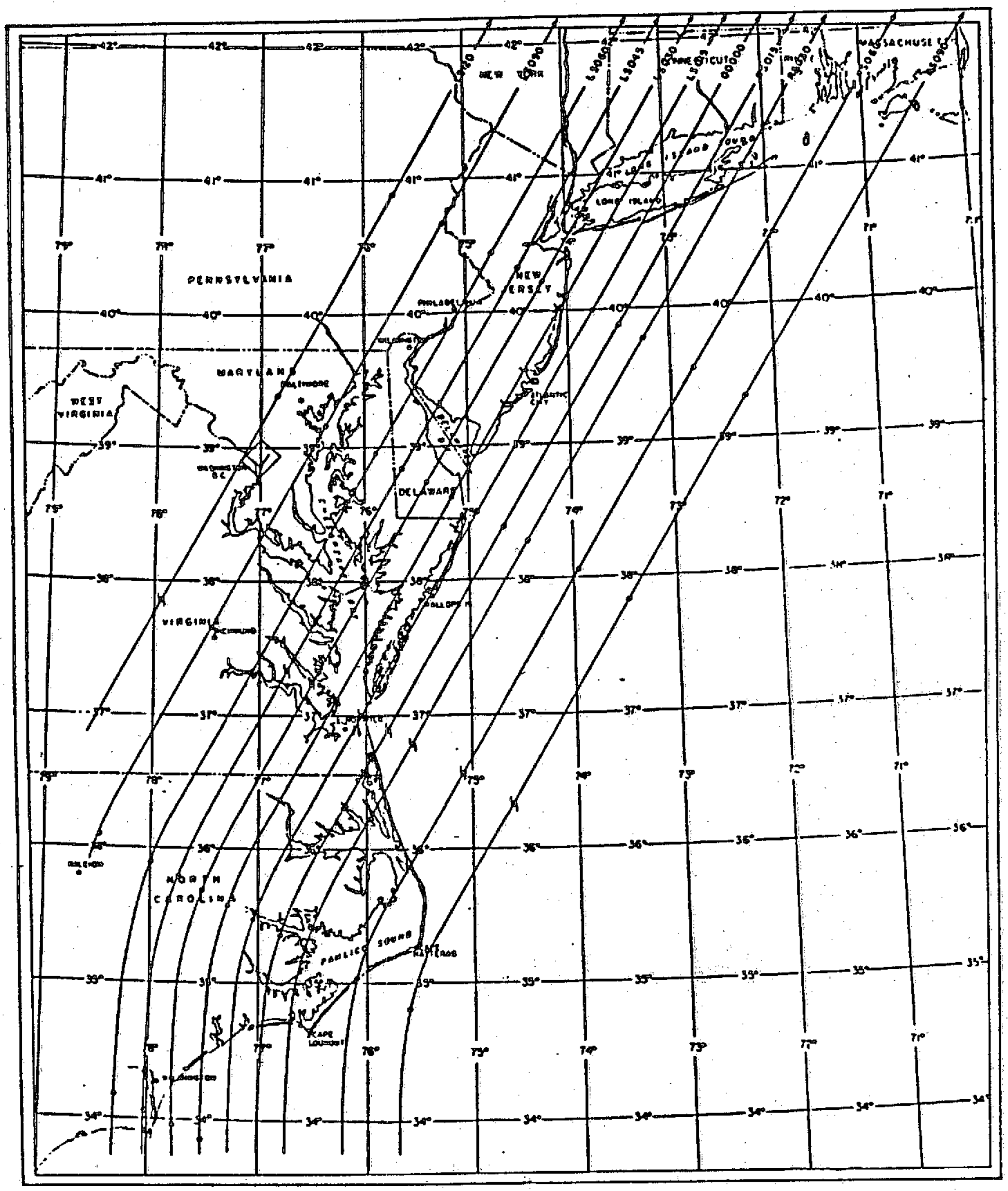


TABLE 2-3

STORM PARAMETERS FOR THE MARYLAND STUDY

DIRECTION	SPEED (mph)	INTENSITIES	TRACKS	RUNS
WNW	20	1 through 4	18	72
NW	20	1 through 4	13	52
NNW	20, 40	1 through 4	10	80
N	20, 40	1 through 4	14	112
NNE	20, 30	1, 2, 3, 4	11, 11, 5, 3	60
NE	20	1 and 2	9 and 4	13

The initial sea surface height set in the Chesapeake Basin SLOSH model was one foot mean sea level (MSL). This initial height, known as the tide anomaly, represents the height of the water surface above mean sea level existing several days in advance of an approaching hurricane. The value for the tide anomaly used in the SLOSH model represents the average sea surface height recorded at tide gages for historical hurricanes prior to landfall.

(3) Maximum Envelopes of Water. (MEOWs) The highest surges reached at all locations within the affected area of the coastline during the passage of a hurricane are called the maximum surges for those locations; the highest maximum surge in the affected area is called the peak surge. The location of the peak surge depends upon where the eye of a hurricane crosses the coastline, hurricane intensity, bathymetry of the basin, configuration of the coastline, approach direction, and the radius of maximum winds of the hurricane. In most instances, the peak surge from a hurricane occurs to the right of the storm path and within a few miles of the radius of maximum winds. Due to the inability to precisely forecast the ultimate landfall location, forward speed, approach direction, and other characteristics of a threatening hurricane, the objective of the hazards analysis is to determine the potential peak surges for all locations within the study area. For that purpose, Maximum Envelopes of Water (MEOWs) are utilized.

The MEOWs were developed by the National Hurricane Center from an array of peak surges calculated for the individual hurricanes modeled for the Chesapeake Basin. MEOWs that disregard storm track can be created for any specified storm parameter, or set of parameters, desired.

Thirty-four MEOWs were initially developed for the Chesapeake SLOSH Basin. These MEOWs consisted of computer printouts showing peak surge values developed for each combination of category and approach direction modeled for the study. The values contained on these original MEOWs were the peak surge height values for each of the model's grid points regardless of where landfall may have occurred.

The results of the thirty-four original MEOWs were analyzed to determine which changes in storm parameters (i.e., intensity and approach direction) resulted in the greatest differences in the values of the peak surges for all locations. In most instances a change in storm intensity accounted for the greatest change in peak surge heights calculated for the SLOSH grid points. A review of the thirty-four MEOW maps showed that, in some cases, the effects of storms in successive categories were so similar that some hurricane categories could be combined without detrimentally affecting evacuation planning. The review also revealed that when compared to changes in hurricane intensity, approach direction had minimal effect in most of the study area.

Subsequently, the National Hurricane Center developed additional Maximum Envelopes of Water (MEOWs of the MEOWs) combining all hurricane approach directions and grouping the hurricane intensities into categories 1, 2, 3, and 4. It is from these MEOWs that the inundation maps shown in Appendix A were developed. These inundation maps illustrate the areas of inundation from peak storm surge heights potentially generated by the four categories of storm intensity considered in this study.

e. Adjustment to SLOSH Model Values. The surge height values contained in the MEOWs represent the water surface elevations produced by the driving forces of the modeled hurricanes in combination with a tide anomaly. The datum for the SLOSH model values and tide anomaly is mean sea level, and tide anomaly values for the entire study area were set at + 1.0 foot, MSL.

(1) Statistical Analysis. Hurricane evacuation decision-makers should keep in mind that the SLOSH model is a mathematical model and does not always give perfect results. To determine the accuracy of the SLOSH model, runs were conducted by the National Weather Service which compared modeled and observed surges at 523 sites for ten hurricane events. The results indicated that the mean absolute error in surge calculated by SLOSH was 1.4 feet, with an error range from -7.1 feet to +8.8 feet. The standard deviation was only 2.0 feet. Approximately 79 percent of the errors fell within one standard deviation of the mean error, which was -0.3 feet. On the average, modeled values were slightly less than those observed.

Based on these results, the National Weather Service estimates that a positive 20 percent adjustment to the SLOSH model values would eliminate most of the potential negative errors occurring from the model. Such an adjustment would add additional surge height to those values that already contain positive errors. Maryland emergency officials agreed to add a positive 20 percent adjustment to the maximum surges for the purposes of inundation mapping and transportation analysis, thus, producing conservative final estimates. All of the analyses for this study, including mapping and evacuation times, reflects this 20 percent adjustment.

(2) Astronomical Tide. The astronomical tide within the Chesapeake Bay is relatively minor and is generally under 1.5 feet. Because of this small tide range, no permanent adjustment to the SLOSH model was made for the Maryland Hurricane Evacuation Study. The emergency management officials in the Maryland study area requested that a 1.0 foot tide height be added to the SLOSH model surges for analytical and mapping purposes. This was done for every case, with the exception of four critical points, where a tide height of 2.0 feet was added. The inundation maps in Appendix A, and the evacuation timing results reflect this treatment of astronomical tide.

Time-History Data

A total of 50 grid points were selected for the time-history tabulation of surge height, wind speed, and wind direction. These grid points were chosen to coincide with critical locations identified by the Local Emergency Management Coordinators for their respective counties. The points are located at low-lying roads and bridges that would be critical to an evacuation, at potentially vulnerable population centers, or at significant natural or manmade barriers. The time-history information, produced by the SLOSH model for the 50 critical points, lists values for still-water surge heights, wind speeds, and wind direction at 10-minute intervals over a 72 hour period.

The purpose of the time-history data is to determine the pre-landfall hazards distance for each of the counties within the study area. Pre-landfall hazards distance, which must be accounted for in evacuation timing, is the distance from the eye of the approaching hurricane to the nearest county boundary at the time an evacuation would be curtailed by hazardous weather conditions. For the Maryland Hurricane Evacuation Study, two conditions that could curtail hurricane evacuation were evaluated: the arrival of sustained gale-force winds (34-knot (39 mph) sustained wind speed, 1-minute average) and the onset of storm surge inundation of low-lying roads, bridges, or other critical areas. The first of these two conditions to occur determines the pre-landfall hazards distance.

The arrival of sustained gale-force winds was chosen as a selected threshold because high-profile vehicles and vehicles pulling campers or boats could easily be overturned, especially on high-rise bridges, by much higher wind gusts accompanying sustained winds. Such accidents would most certainly cripple or stop traffic flow on that evacuation route. Boat and camper owners should be encouraged to store their boats, trailers, and campers on high ground 48 hours before anticipated hurricane arrival rather than pulling them during an evacuation. The arrival of sustained gale-force winds is also the time, under the majority of hurricane threats, when the heaviest rainfall begins. Generally, one-half of the total amount of rainfall received from a hurricane occurs from the time of arrival of sustained gale-force winds to the time the eye reaches the coastline.

The second condition limiting evacuation, the onset of storm surge inundation, will not be a significant factor in most of the study area prior to the arrival of sustained gale-force winds. Storm surge is the increase in height of the surface of the sea due to the forces of the approaching hurricane. At virtually all SLOSH time-history critical points, the arrival of sustained gale-force winds is expected to occur before the onset of storm surge inundation and, therefore, determines the pre-landfall hazards distance. Evacuation decision-making officials should be aware that the coincidence of high astronomical tide with storm surge could cause moderate flooding at low-lying critical points prior to the arrival of sustained gale-force winds computed by the SLOSH model.

Maximum surge heights were calculated for hundreds of points in the study area. Table 2-4 lists the maximum surge heights for the fifty critical points designated by the local emergency management officials in the Maryland study area. These values are the maximum surges computed by the SLOSH model, assuming an initial tide anomaly of one foot mean sea level, and they provide a sampling of maximum surge heights throughout the study region. Values for both raw SLOSH data and for the adjustments, which are discussed below, are listed in Table 2-4 under the headings "raw" and "adj", respectively.

As agreed by the Maryland emergency officials, two adjustments were made to these surge heights before further analyses were conducted. A one foot tide height (2 feet for 4 of the 50 critical points) and an additional 20 percent adjustment were added to these figures to account for any possible underestimation by the SLOSH model. The clearance and evacuation times calculated in the transportation analysis were based upon these adjusted values. The adjustments were discussed further in an earlier section of this chapter. The inundation maps, which are presented in Appendix A, list the maximum surge heights for various locations in each county. The surge height values listed on the inundation maps were determined by adjusting the raw SLOSH data in the manner described above. The number and location of these points depends upon the variability of surge heights within a given county, and do not necessarily coincide directly with the fifty critical points in Table 2-4.

Since the limiting factor for hurricane evacuation in the study area is the arrival of sustained gale-force winds, the pre-landfall hazards distance for any county can be defined as the distance to the eye of the approaching hurricane upon the arrival of sustained gale-force winds, or the radius of sustained gale-force winds of the threatening hurricane. Thus, for the Maryland Hurricane Evacuation Study area, the pre-landfall hazards distance and the radius of sustained gale-force winds are synonymous.

Although the windfields of actual hurricanes can vary significantly from one storm to another, as well as within the same storm over time, the SLOSH model calculates a quasi-symmetrical windfield. This means that the wind speeds are distributed almost evenly around the modeled storm. After analyzing data extracted from the time-history information produced by the Chesapeake Basin SLOSH model, the National Hurricane Center has concluded that the radii of gale-force winds calculated by the model are essentially independent of hurricane forward speed and approach direction, but dependent upon hurricane strength. Thus, there is a radius of gale-force winds associated with each of the four hurricane categories that is independent of forward speed and approach direction, and is valid for any location within the study area. This radius from storm center

TABLE 2-4
SLOSH MODELED MAXIMUM SURGE HEIGHTS
AT LOCATIONS OF CRITICAL POINTS

POINT NO.	SLOSH CRITICAL POINT	COUNTY	MAXIMUM SURGE HEIGHTS (IN FEET) CATEGORY 1 RAW	ADJ	CATEGORY 2 RAW	ADJ	CATEGORY 3 RAW	ADJ	CATEGORY 4 RAW	ADJ
1	Ocean City	Worcester	4.0	6.0	7.2	9.8	9.8	13.0	12.3	16.0
2	South Point	Worcester	2.2	3.8	3.6	5.5	10.9	14.3	16.4	20.9
3	Point Lookout	St. Mary's	2.6	4.3	4.2	6.2	5.8	8.2	7.7	10.4
4	St. George	St. Mary's	8.4	11.3	6.8	9.4	7.2	9.8	7.6	10.3
5	Coltons Point	St. Mary's	3.1	4.9	5.2	7.4	7.7	10.4	10.2	13.4
6	Cobb Island	Charles	3.1	4.9	5.4	7.7	7.9	10.7	10.3	13.6
7	Bridge 301	Charles	3.1	4.9	5.8	8.2	8.7	11.6	11.7	15.2
8	Port Tobacco	Charles	3.9	5.9	6.4	8.9	9.6	12.7	12.7	16.4
9	Mount Vernon	Somerset	2.9	4.7	4.0	6.0	4.9	7.1	7.3	10.0
10	Washington, D.C.	Independent City	3.0	4.8	4.4	6.5	5.5	7.8	8.7	11.6
11	Cedar Point	Charles	3.0	4.8	4.8	7.0	6.6	9.1	8.9	11.9
12	Town Creek	St. Mary's	3.1	4.9	5.2	7.4	6.6	9.1	8.6	11.5
13	Bridge 231	St. Mary's	3.2	5.0	5.5	7.8	8.0	10.8	10.2	13.4
14	Lower Marlboro	Calvert	4.0	6.0	6.9	9.5	10.1	13.3	13.0	16.8
15	Cove Point	Calvert	3.0	4.8	4.9	7.1	6.8	9.4	9.0	12.0
16	Chesapeake Beach	Calvert	2.9	4.7	4.5	6.6	5.9	8.3	8.0	10.8
17	Columbia Beach	Anne Arundel	3.0	4.8	4.7	6.8	6.3	8.8	8.5	11.4
18	Thomas Point	Anne Arundel	3.1	4.9	5.1	7.3	6.9	9.5	9.3	12.4
19	Riva, South Riv.	Anne Arundel	4.1	6.1	6.4	8.9	9.1	12.1	12.3	16.0
20	Annapolis	Anne Arundel	2.8	4.6	4.4	6.5	5.5	7.8	7.4	10.1
21	Severn, Horn Pt.	Anne Arundel	4.1	6.1	6.1	8.5	7.6	10.3	10.4	13.7
22	Gibson Island	Anne Arundel	2.8	4.6	4.5	6.6	5.9	8.3	7.9	10.7
23	Baltimore	Independent City	3.6	5.5	5.8	8.2	6.1	8.5	8.6	11.5
24	Swan Point	Baltimore	3.3	5.2	5.3	7.6	6.4	8.9	8.7	11.6
25	Rosedale	Baltimore	3.5	5.4	6.6	9.1	6.7	9.2	9.1	12.1
26	Middle River	Baltimore	3.7	5.6	6.4	8.9	7.0	9.6	9.6	12.7
27	Gunpowder	Baltimore	3.7	5.6	7.1	9.7	7.2	9.8	10.6	13.9
28	Havre De Grace	Harford	3.2	5.0	5.5	7.8	5.8	8.2	8.0	10.8
29	North East	Cecil	3.0	4.8	7.1	9.7	5.3	7.6	8.4	11.3
30	C&O Canal	New Castle, DE	3.7	5.6	6.7	9.2	5.8	8.2	8.7	11.6
31	Bay View	Cecil	3.2	5.0	5.7	8.0	5.5	7.8	7.9	10.7
32	Betterton	Kent	3.3	5.2	5.7	8.0	5.8	8.2	8.2	11.0
33	Rock Hall	Kent	3.1	4.9	5.1	7.3	6.3	8.8	8.6	11.5
34	Chester River	Kent	3.9	5.9	6.9	9.5	7.3	10.0	10.5	13.8
35	Kent Narrows	Queen Anne's	3.0	4.8	5.1	7.3	6.2	8.6	8.0	10.8
36	Kent Island	Queen Anne's	2.9	4.7	4.7	6.8	5.6	7.9	7.4	10.1
37	Grasonville	Talbot	3.6	5.5	5.9	8.3	6.9	9.5	8.2	11.0
38	Tilghman	Talbot	3.0	4.8	4.9	7.1	6.4	8.9	9.0	12.0
39	St. Michaels	Talbot	3.5	5.4	5.8	8.2	6.8	9.4	9.4	12.5
40	Oxford	Talbot	3.5	5.4	6.2	8.6	6.8	9.4	8.9	11.9
41	Cambridge	Dorchester	3.2	5.0	4.0	6.0	4.3	6.4	6.0	8.4
42	Taylors Island	Dorchester	3.0	4.8	5.1	7.3	5.6	7.9	6.8	9.4
43	Hoopers Island	Dorchester	3.0	4.8	5.0	7.2	6.9	9.5	8.9	11.9
44	Elliott	Dorchester	2.8	4.6	5.6	7.9	6.8	9.4	9.5	12.6
45	Nanticoke	Wicomico	3.0	4.8	6.6	9.1	6.8	9.4	9.7	12.8
46	Wicomico	Charles	3.1	4.9	6.3	8.8	5.8	8.2	8.5	11.4
47	Deal Island	Somerset	2.8	4.6	5.5	7.8	6.4	8.9	8.5	11.4
48	Rumbley	Somerset	3.0	4.8	6.0	8.4	6.4	8.9	9.0	12.0
49	Crisfield	Somerset	2.7	4.4	5.3	7.6	5.8	8.2	7.9	10.7
50	Smith Island	Somerset	2.8	4.6	4.3	6.4	5.9	8.3	7.4	10.1

represents the distance in nautical miles that sustained gale-force winds extend from the centers of the hurricanes simulated for the study.

Table 2-5 lists the SLOSH radii of sustained gale-force winds by category of hurricane for the Maryland Hurricane Evacuation Study area. These are hypothetical values extracted from the SLOSH model and represent typical distances to the hurricane eye upon the arrival of sustained gale-force winds at the boundary of each county. These distances should be used as an approximation for planning purposes or when no actual observations are available. Marine advisories, produced by the National Hurricane Center every 6 hours, give the measured distance in nautical miles of the 34-knot (39 mph), 1-minute sustained wind speed from the eye of an approaching hurricane. These distances are given for the four quadrants of a hurricane (i.e., northwest, northeast, southeast, southwest).

Forecasts of these distances for 12, 24, 48, and 72 hour periods are also given. When actual measured distances of the radius of 34-knot, 1-minute sustained winds are available, the largest radius should be used for evacuation decision-making. Further discussion of the application of the radius of gale-force winds to hurricane evaluation decision-making is contained in Chapter 7, Decision Arcs.

TABLE 2-5

SLOSH RADII OF GALE-FORCE WINDS

Saffir/Simpson Hurricane Category	Radius of Gale-Force (34 knot/39 mph) Winds (Nautical Miles)	(Statute Miles)
1	60	69
2	85	98
3	105	121
4	125	144

Wave Effect

The SLOSH model does not provide data concerning the additional height of waves generated on top of the still-water storm surge. Generally, waves do not add significantly to the area flooded by storm surge and can usually be ignored except for locations immediately along the open coastline or the shorelines of very large sounds and estuaries where significant fetch lengths and water depths may exist. Since near-shore wave phenomena under hurricane conditions are not well understood, it is assumed that, for the open coast, maximum theoretical wave heights based upon relationships of fetch length to water depth occur near the time of landfall. Due to the presence of structures, dunes, or vegetation, the waves break and their energy dissipates within a few hundred yards of the coastline.

It is perhaps more important for evacuation planning purposes to consider potential wave effects for less than sustained gale-force wind speeds. The rationale here is to determine if wave action above still-water surge heights will exceed the elevations of roads, bridges, or other critical areas near the coastline, thereby increasing the pre-landfall hazards distances.

Before making calculations of wave height and runup at critical locations within the study area, surge heights at the time of arrival of sustained gale-force winds should be considered. A review of the SLOSH time-histories shows that maximum surges at critical points within the study area at the time of arrival of gale-force winds are on the order of 3.0 feet MSL or less. Since tides of this magnitude are experienced fairly routinely without major traffic problems, calculations of wave height and runup were not made; however, evacuation planners should be aware that low-lying sections of some highways could be subject to minor wave action prior to the arrival of sustained gale-force winds.

Freshwater Flooding

Amounts and arrival times of rainfall associated with hurricanes are highly unpredictable. For most hurricanes, the heaviest rainfall begins near the time of arrival of sustained gale-force winds; however, heavy rains in amounts exceeding 20 inches can precede an approaching hurricane by as much as 24 hours. Unrelated weather systems can also contribute significant rainfall amounts within a basin in advance of a hurricane.

Due to the unpredictability of rainfall from hurricanes, no attempt was made to employ sophisticated modeling or analysis in quantifying the effects of rainfall for the Maryland Hurricane Evacuation Study area. Areas, facilities, and evacuation roadways which have historically flooded during periods of heavy rainfall were identified throughout the study area and assumed to be vulnerable to freshwater flooding under hurricane threats. More detailed information concerning flood stages from stream and river flooding may be obtained from the U.S. Army Corps of Engineers, Baltimore District, or from the Federal Emergency Management Agency.

CHAPTER THREE

VULNERABILITY ANALYSIS

Purpose

The purpose of the vulnerability analysis is to identify the area, populations, and facilities which are potentially vulnerable to flooding associated with hurricanes. The storm surge data from the hazards analysis were used to develop inundation maps (see Appendix A), evacuation zones, and evacuation scenarios for each of the study area counties; to quantify the population at risk under a range of hurricane intensities; and to identify major medical/institutional and other facilities that are potentially vulnerable to storm surge.

Hurricane Evacuation Zones

Evacuation zones have been developed for each of the Maryland Hurricane Evacuation Study area counties. Each of the evacuation zones are delineated as much as possible using major natural or man-made geographic features and conform to existing political or demographic boundaries (i.e., Census tracts or traffic analysis zones) within each county. The purpose for this delineation is to aid in the development of population and other socioeconomic data to be used in traffic modeling; to determine sheltering requirements; to facilitate future updating; and to simplify the evacuation warning procedure. County evacuation zones are presented in Appendix A for Anne Arundel and St. Mary's Counties, Ocean City, and for each Eastern Shore county.

Hurricane Evacuation Scenarios

a. General. Hurricane evacuation scenarios have been developed for each of the Maryland Hurricane Evacuation Study area counties. The evacuation scenarios are groups of evacuation zones that will be threatened by storm surge from specific hurricane intensity categories. In many instances, the same evacuation zones are threatened by a range of intensity categories. In those cases, the zones requiring evacuation have been combined into evacuation scenarios based on combinations of hurricane intensities.

b. County Scenarios. Table 6-2 in Chapter 6 contains the hurricane evacuation scenarios developed for each of the Eastern Shore counties and lists the evacuation zones comprising each scenario. Maps illustrating hurricane evacuation zones for Anne Arundel County, St. Mary's County, Ocean City, and the Eastern Shore counties are contained in Appendix A.

Vulnerable Population

The vulnerable population within each of the study area counties is comprised of those persons residing within the areas subject to storm surge inundation, as well as the residents of mobile homes located in non-vulnerable zones. The areas subject to inundation are further broken down into evacuation zones which are defined for three major purposes: (1) to determine the number of evacuees seeking shelter, (2) to determine the number of vehicles entering the roadway network, and (3) to help local officials inform the public which areas of the county must evacuate during a storm. Due to their greater vulnerability to hurricane strength winds, all mobile home residents are included in the evacuation population of each evacuation zone.

As discussed in Chapter One, the limited vulnerable areas of the Western Shore counties are expected to generate much less evacuation traffic than the Eastern Shore counties.

This study is based upon the assumption that the evacuation clearance times for the Western Shore counties will be equal to the expected response times, which are discussed in Chapter Four. A complete transportation analysis of two Western Shore counties, Anne Arundel and St. Mary's, indicated that this assumption was correct. Thus, for the remaining Western Shore counties (Baltimore, Calvert, Charles, Cecil, Harford, Prince George's, and Baltimore City), no transportation analysis was performed. Consequently, inundated areas were not broken down into evacuation zones for these Western Shore counties.

Table 3-1 presents the vulnerable populations for each of the counties for which evacuation zones were determined. An estimate of the number of evacuees seeking public shelter is also provided. These figures are based on the projected 1989 population data shown in the table.

Institutions, Medical Facilities, and Trailer Parks

Inventories of institutions, medical facilities, and trailer parks have been compiled for each of the study area counties. The purpose of this analysis is to determine which of these institutions and facilities may require evacuation under various hurricane threats. Because mobile homes are particularly vulnerable to the high winds which accompany hurricanes, trailer parks are included among the list of facilities as a convenient identification tool for emergency officials. The first floor elevations of all medical facilities in or near areas vulnerable to storm surge have been established. The names and capacities for the institutional/medical facilities and trailer parks within each of the Maryland Hurricane Evacuation Study area counties are presented in Tables 3-2 through 3-19. The "map key" on these tables corresponds to the locations of all facilities and trailer parks on the inundation maps provided in Appendix A.

TABLE 3-1
VULNERABLE POPULATION
BY STORM SCENARIO AND COUNTY

COUNTY	1989 POPULATION ESTIMATE	STORM CATEGORY	VULNERABLE POPULATION	PEOPLE GOING TO PUBLIC SHELTER
Anne Arundel	423,475	1-2, low season	44,540	4,530
		1-2, high season	48,540	4,730
		3-4, low season	54,330	5,845
		3-4, high season	59,015	6,080
Caroline	24,545	1-4	2,860	750
Dorchester	30,070	1	6,460	630
		2-3	8,160	790
		4	12,780	1,465
Kent	16,965	1-4	3,040	550
Queen Anne's	32,565	1-2	11,470	1,395
		3-4	17,620	2,290
St. Mary's	71,075	1-4	16,215	3,465
Somerset	21,700	1	13,210	840
		2-3	14,985	990
		4	16,365	1,175
Talbot	28,580	1	9,070	1,085
		2-4	12,660	1,630
Wicomico	72,465	1	5,200	1,100
		2-3	6,670	1,250
		4	8,155	1,480
Worcester (figures include Ocean City population)	37,745 (permanent)	1-2, November	20,810	1,645
		1-2, shoulder weekend	91,600	5,180
		1-2, summer weekday	132,050	7,200
		1-2, summer weekend	212,950	11,250
		3-4, November	30,135	2,640
		3-4, shoulder weekend	117,425	7,000
		3-4, summer weekday	167,305	9,495
		3-4, summer weekend	286,815	19,420
Ocean City	250,000 (seasonal maximum)	1-2, November	13,575	685
		1-2, shoulder weekend	83,505	4,480
		1-2, summer weekday	123,465	6,175
		1-2, summer weekend	203,385	10,175
		3-4, November	18,125	1,010
		3-4, shoulder weekend	104,555	5,330
		3-4, summer weekday	153,945	7,800
		3-4, summer weekend	252,730	12,740

TABLE 3-2

INSTITUTIONS, MEDICAL FACILITIES, AND TRAILER PARKS
ANNE ARUNDEL COUNTY

MAP KEY	FACILITY	TYPE
B1 -	Annapolis Convalescent Center	Nursing Home
B2 -	Arundel Geriatric & Nursing Center	Nursing Home
B3 -	Bay Manor Nursing Home	Nursing Home
B4 -	Crofton Convalescent	Nursing Home
B5 -	Fairfield Nursing Center	Nursing Home
B6 -	Knollwood Manor	Nursing Home
B7 -	MD Manor of Glen Burnie	Nursing Home
B8 -	Meridian Nursing Center - Hammonds Ln	Nursing Home
B9 -	Meridian Nursing Center - Severna Park	Nursing Home
B10 -	N. Arundel Nursing & Convalescent Center	Nursing Home
B11 -	Pleasant Living Convalescent Center	Nursing Home
B12 -	Hope House	Nursing Home
B13 -	Meadows Recovery Center	Nursing Home
B14 -	Bello Machre	Nursing Home
B15 -	Morris Hill Care Home	Nursing Home
C1 -	Anne Arundel General Hospital	Hospital
C2 -	North Arundel Hospital	Hospital
C3 -	Crownsville Hospital Center	Hospital
D1 -	MD House of Correction	Prison
D2 -	MD Correctional Institution	Prison
D3 -	MD Correctional Institution	Prison
D4 -	MD Correctional Institution	Prison
D5 -	MD Correctional Institution	Prison
E1 -	Bells Trailer Park	Trailer Park
E2 -	Boones Mobile Estates	Trailer Park
E3 -	Colonial Manor Estates	Trailer Park
E4 -	Crestwood Trailer Park	Trailer Park
E5 -	Dogwood Trailer Park	Trailer Park
E6 -	J & J Trailer Park	Trailer Park
E7 -	Holiday Trailer Park	Trailer Park
E8 -	Lyons Creek Mobile Home Estates	Trailer Park
E9 -	Maryland Manor Homes	Trailer Park
E10 -	Del-Ray Trailer Park	Trailer Park
E11 -	Patuxent Mobile Estates	Trailer Park
E12 -	Rio Vista Plaza	Trailer Park
E13 -	Ridgewood Trailer Park	Trailer Park
E14 -	Rol-Park Trailer Park	Trailer Park
E15 -	Severn Mobile Home Park	Trailer Park
E16 -	Trails End Trailer Park	Trailer Park
E17 -	Wayson's Trailer Park	Trailer Park
E18 -	Chesapeake Mobile Court	Trailer Park
E19 -	Ed-Mar Trailer Park	Trailer Park
E20 -	Frank & Bill's Trailer Park	Trailer Park
E21 -	Terrace View Mobile Estates	Trailer Park
E22 -	Chewning Mobile Home Park	Trailer Park

TABLE 3-2 (Continued)

E23 - Arundel Mobile Village	Trailer Park
E24 - Millersville Trailer Park	Trailer Park
E25 - Odenton Flower Knowl Park	Trailer Park
E26 - Parkway Village	Trailer Park
E27 - Welch's Trailer Park	Trailer Park
E28 - Summerhill Mobile Home Park	Trailer Park

TABLE 3-3

INSTITUTIONS, MEDICAL FACILITIES, AND TRAILER PARKS
BALTIMORE CITY

MAP KEY	FACILITY	TYPE
B1 -	Alice Manor	Nursing Home
B2 -	Ashburton Nursing Home	Nursing Home
B3 -	Belair Convalescent	Nursing Home
B4 -	Century Home	Nursing Home
B5 -	Crawford Retreat	Nursing Home
B6 -	John L. Deaton Medical Center	Nursing Home
B7 -	Dukeland Nursing & Convalescent Center	Nursing Home
B8 -	Edenwald (located in Baltimore County)	Nursing Home
B9 -	Meridian Homewood Nursing Center	Nursing Home
B10 -	Evergreen South Nursing Center	Nursing Home
B11 -	Friedler's Guest Home	Nursing Home
B12 -	Inns of Evergreen	Nursing Home
B13 -	Garrison Nursing Home	Nursing Home
B14 -	Liberty Nursing Home	Nursing Home
B15 -	Franklin Court Nursing Center	Nursing Home
B16 -	Garedon Nursing Home	Nursing Home
B17 -	Harford Gardens Convalescent Center	Nursing Home
B18 -	Haven Nursing Home	Nursing Home
B19 -	Hayes Care Home	Nursing Home
B20 -	Jenkins Memorial	Nursing Home
B21 -	Kenesaw Nursing Home	Nursing Home
B22 -	Kenson Nursing Home	Nursing Home
B23 -	Keswick Home	Nursing Home
B24 -	Key Circle Hospice	Nursing Home
B25 -	Francis Scott Key Medical Center	Nursing Home
B26 -	Inns of Evergreen Center	Nursing Home
B27 -	Lake Drive Nursing Home	Nursing Home
B28 -	Levindale Hebrew Geriatric Center	Nursing Home
B29 -	Lincoln Convalescent Center	Nursing Home
B30 -	Maryland Baptist Aged Home	Nursing Home
B31 -	Maryland Rehab Center	Nursing Home
B32 -	Melchor Nursing Home	Nursing Home
B33 -	Cape Manor Meridian Nursing Center	Nursing Home
B34 -	Meridian Nursing Center - Hamilton	Nursing Home
B35 -	Meridian Nursing Center - Long Green	Nursing Home
B36 -	Pimlico Elder Care	Nursing Home
B37 -	Mount Vernon Care Center	Nursing Home
B38 -	Northwest & Convalescent Center	Nursing Home
B39 -	Park Manor Nursing Home	Nursing Home
B40 -	Inn of Evergreens (Northwest)	Nursing Home
B41 -	Pleasant Manor Nursing Center	Nursing Home
B42 -	Poplar Manor Nursing Home	Nursing Home
B43 -	Roland Park Place	Nursing Home
B44 -	Seton Hill Manor	Nursing Home
B45 -	Upland Home for Church Women	Nursing Home

TABLE 3-3 CONTINUED

B46 - Villa St. Michael	Nursing Home
B47 - Wesley House	Nursing Home
B48 - Balt. Addictions Treatment Center	Nursing Home
B49 - Francis Scott Key Alcoholism Center	Nursing Home
B50 - Quarterly Way Houses	Nursing Home
B51 - Church Home Corporation	Nursing Home
B52 - Pendleton House	Nursing Home
B53 - Curtis Hall	Nursing Home
B54 - Ivy Delica Domiciliary Care Home	Nursing Home
B55 - Miracle Deliverance Home	Nursing Home
B56 - Park Ave. Home for Aged	Nursing Home
B57 - Pipesh Domiciliary Care Home	Nursing Home
B58 - Powell's Domiciliary Home	Nursing Home
B59 - Uplands Home for Church Women	Nursing Home
B60 - Wesley Home	Nursing Home
B61 - Zion Church Home	Nursing Home
B62 - Reg. Inst for Children & Adoles.	Nursing Home
B63 - Woodburne Center	Nursing Home
B64 - Walter P. Carter Center	Nursing Home
B65 - Highland Health Facility	Nursing Home
C1 - Bon Secours Hospital	Hospital
C2 - Church Hospital Corporation	Hospital
C3 - Good Samaritan Hospital	Hospital
C4 - *Johns Hopkins Hospital	Hospital
C5 - Francis Scott Key Medical Center	Hospital
C6 - Lutheran Hospital of MD	Hospital
C7 - MD Gen Hospital	Hospital
C8 - Mercy Hospital	Hospital
C9 - Homewood Center (South)	Hospital
C10 - Liberty Medical Center	Hospital
C11 - St. Agnes Hospital of Balt.	Hospital
C12 -*Sinai Hospital of Balt.	Hospital
C13 - South Gen Hospital of Balt.	Hospital
C14 - Union Mem. Hospital	Hospital
C15 -*Univ. of MD Hospital	Hospital
C16 - Homewood Center (North)	Hospital
C17 - Children's Hospital	Hospital
C18 - John L. Deaton Medical Center	Hospital
C19 - Keswick Home	Hospital
C20 -*Francis Scott Key Medical Center	Hospital
C21 - Levindale Hebrew Geriatric Center	Hospital
C22 - Montebello Center	Hospital
C23 - Mt. Washington Pediatric Hospital	Hospital
C24 - Walter P. Carter Center	Hospital
C25 - Gundy Glass Hospital	Hospital
C26 - Highland Health Facility	Hospital
C27 - MD Penitentiary Hospital	Hospital
C28 - Kennedy Institute	Hospital
C29 - James Lawrence Kernan Hospital	Hospital

* Shock Trauma Center

TABLE 3-3 CONTINUED

D1 - MD Penitentiary	Prison
D2 - Balt. City Correctional Center	Prison
D3 - Balt. Pre-Release Unit	Prison
D4 - Pre-Release Unit for Women	Prison
D5 - Dismas House - East	Prison
D6 - Dismas House - West	Prison
D7 - Threshold	Prison
D8 - MD Recep., Diagnos., & Class.	Prison

TABLE 3-4

INSTITUTIONS, MEDICAL FACILITIES, AND TRAILER PARKS
BALTIMORE COUNTY

MAP KEY	FACILITY	TYPE
B1 -	Armacost Nursing Home	Nursing Home
B2 -	Augsburg Lutheran Home of MD	Nursing Home
B3 -	Baptist Home of MD	Nursing Home
B4 -	Bent Nursing Home	Nursing Home
B5 -	Breightonwood	Nursing Home
B6 -	Broadmead	Nursing Home
B7 -	Chapel Hill Convalescent Home	Nursing Home
B8 -	Dulaney Towson Nursing & Convalescent	Nursing Home
B9 -	Eastpoint Nursing Home	Nursing Home
B10 -	Forest Haven Nursing Home	Nursing Home
B11 -	Frederick Villa Nursing Center	Nursing Home
B12 -	Garrison Valley Center	Nursing Home
B13 -	Holly Hill Manor	Nursing Home
B14 -	Hurwitz House	Nursing Home
B15 -	Inglenook	Nursing Home
B16 -	Ivy Hall Ger. Center	Nursing Home
B17 -	Jewish Convalescent Center Scotts	Nursing Home
B18 -	Little Sisters of the Poor	Nursing Home
B19 -	Manor Care - Rossville	Nursing Home
B20 -	Manor Care - Ruxton	Nursing Home
B21 -	Manor Care - Towson	Nursing Home
B22 -	Stella Maris Hospice	Nursing Home
B23 -	Maryland Masonic Homes	Nursing Home
B24 -	Meridian Nursing Center - Caton.	Nursing Home
B25 -	Meridian Nursing Center - Heritage	Nursing Home
B26 -	Meridian Nursing Center - Randalls.	Nursing Home
B27 -	Milford Manor Nursing Home	Nursing Home
B28 -	Multi-Medical Convalescent & Nursing Ctr	Nursing Home
B29 -	Old Court Nursing Center	Nursing Home
B30 -	Perring Pkwy Nursing Home	Nursing Home
B31 -	Pickersgill	Nursing Home
B32 -	Pikesville Nursing & Convalescent Center	Nursing Home
B33 -	Presbyterian Home of MD	Nursing Home
B34 -	Ridgeway Manor	Nursing Home
B35 -	Riverview Nursing Center	Nursing Home
B36 -	Katherine Robb Nursing Home	Nursing Home
B37 -	St. Joseph's Nursing Home	Nursing Home
B38 -	St. Luke Lutheran Home	Nursing Home
B39 -	Summit Nursing Home	Nursing Home
B40 -	Tawes/Bland Bryant Nursing Center	Nursing Home
B41 -	Towson ConvalescentHome	Nursing Home
B42 -	Valley Nursing & Convalescent Center	Nursing Home
B43 -	Valley View Nursing Home	Nursing Home
B44 -	No listing for this number	-
B45 -	Augsburg Lutheran Home of MD	Nursing Home

TABLE 3-4 CONTINUED

B46 - Repeat listing of B3	
B47 - Broadmead	Nursing Home
B48 - Charlestown Retirement Community	Nursing Home
B49 - College Manor	Nursing Home
B50 - Francis X. Gallagher Center	Nursing Home
B51 - Good Shepard Center	Nursing Home
B52 - Villa Maria	Nursing Home
C1 - Balt. Co. Gen Hospital	Hospital
C2 - Franklin Square Hospital	Hospital
C3 - Greater Balt. Medical Center	Hospital
C4 - St. Joseph Hospital	Hospital
C5 - Walter P. Carter Center at Catonsville	Hospital
C6 - Sheppard & Enoch Pratt Hospital	Hospital
C7 - Spring Grove Hospital	Hospital

TABLE 3-5

INSTITUTIONS, MEDICAL FACILITIES, AND TRAILER PARKS
CALVERT COUNTY

MAP KEY	FACILITY	TYPE
B1	Calvert Co. Nursing Center	Nursing Home
B2	Calvert House Corporation	Nursing Home
C1	Calvert Memorial Hospital	Hospital
E1	Anchorage Park Trailer Park	Trailer Park
E2	Bayview Manor Trailer Park	Trailer Park
E3	Bright Acres Trailer Park	Trailer Park
E4	Calvert Trailer Park	Trailer Park
E5	Regency Manor Trailer Park	Trailer Park

TABLE 3-6

INSTITUTIONS, MEDICAL FACILITIES, AND TRAILER PARKS
CAROLINE COUNTY

MAP KEY	FACILITY	TYPE
B1	Caroline Nursing Home, Inc.	Nursing Home
B2	Wesleyan Health Care Center, Inc.	Nursing Home
B3	Christian Care Home	Nursing Home
B4	Greensboro Community Care Home	Nursing Home
B5	Benedictine Sch. for Exept. Children	Nursing Home
D1	Caroline Co. Detention Center	Prison
E1	Liberty Trailer Park	Trailer Park
E2	Swann's Trailer Park	Trailer Park
E3	Mobile Home Park	Trailer Park
E4	Towers Mobile Home Court	Trailer Park
E5	Nelphine Mobile Home Park	Trailer Park
E6	Sunny Pines	Trailer Park
E7	Hilltop Trailer Park	Trailer Park
E8	Holly Cove Harbor Park	Trailer Park
E9	Taylors Trailer Park	Trailer Park
E10	Tilghman Brothers Park	Trailer Park
E11	Meadow Brook Court	Trailer Park
E12	Caroline Acres	Trailer Park
E13	Cedars Mobile Home Park	Trailer Park
E14	Russels Trailer Park	Trailer Park
E15	Oil City Trailer Park	Trailer Park
E16	Shady Acres	Trailer Park
E17	Marsh Creek Trailer Park	Trailer Park

TABLE 3-7
INSTITUTIONS, MEDICAL FACILITIES, AND TRAILER PARKS
CECIL COUNTY

MAP KEY	FACILITY	TYPE
B1 -	Calvert Manor	Nursing Home
B2 -	Devine Haven Convalescent	Nursing Home
B3 -	Laurelwood Nursing Home	Nursing Home
C1 -	Union Hospital	Hospital
C2 -	VA Hospital	Hospital
C3 -	Cecil/Kent Health Services	Hospital
C4 -	Sun Medical Center	Hospital

TABLE 3-8
INSTITUTIONS, MEDICAL FACILITIES, AND TRAILER PARKS
CHARLES COUNTY

MAP KEY	FACILITY	TYPE
B1 -	Charles Co. Nursing Home	Nursing Home
B2 -	Meridian Nursing Home	Nursing Home
B3 -	The Jude House	Nursing Home
C1 -	Physicians Mem. Hospital	Hospital
E1 -	Gillespie Trailer Park	Trailer Park
E2 -	Idlewood Trailer Park	Trailer Park

TABLE 3-9
INSTITUTIONS, MEDICAL FACILITIES, AND TRAILER PARKS
DORCHESTER COUNTY

MAP KEY	FACILITY	TYPE
B1 -	Mallard Bay Nursing Home	Nursing Home
B2 -	Glasgow Nursing Home	Nursing Home
B3 -	New Beginnings at Warwick Manor	Nursing Home
B4 -	William Hill Health Center	Nursing Home
B5 -	New Beginnings at White Oak	Rehab. Ctr
C1 -	Dorchester General Hospital	Hospital
C2 -	Eastern Shore Hospital Center	Hospital
D1 -	County Jail	Jail
E1 -	Dorchester Mobile Home Village	Trailer Park
E2 -	Handy Trailer Park	Trailer Park
E3 -	Dorman Trailer Park	Trailer Park
E4 -	Heritage Trailer Park	Trailer Park
E5 -	Beaver Neck Village Trailer Park	Trailer Park

TABLE 3-10

INSTITUTIONS, MEDICAL FACILITIES, AND TRAILER PARKS
HARFORD COUNTY

MAP KEY	FACILITY	TYPE
B1 -	Bel Air Convalescent Center	Nursing Home
B2 -	Brevin Nursing Home	Nursing Home
B3 -	Citizens Nursing Home of Harford Co.	Nursing Home
B4 -	Ashley	Nursing Home
B5 -	New Beginnings at Hidden Brook	Nursing Home
C1 -	Fallston General Hospital	Hospital
C2 -	Harford Memorial Hospital	Hospital
E1 -	B & J Trailer Park	Trailer Park
E2 -	Bay View Motor Home Park	Trailer Park
E3 -	Swan Harbor Dell Trailer Park	Trailer Park
E4 -	Bavers Motor Home Park	Trailer Park

TABLE 3-11

INSTITUTIONS, MEDICAL FACILITIES, AND TRAILER PARKS
KENT COUNTY

MAP KEY	FACILITY	TYPE
A12 -	Kent County Court House	Municipal
A13 -	Detention Center	Prison
B1 -	Magnolia Hall	Nursing Home
B2 -	A.F. Whitsitt Alcoholism Rehab. Center	Nursing Home
C1 -	Kent & Queen Anne's Hospital	Hospital
C2 -	Upper Shore Com. Mental Health Center	Hospital
E1 -	Circle Park Trailer Park	Trailer Park
E2 -	Trailer Park	Trailer Park
E3 -	Trailer Park	Trailer Park
E4 -	Trailer Park	Trailer Park

TABLE 3-12

INSTITUTIONS, MEDICAL FACILITIES, AND TRAILER PARKS
PRINCE GEORGE'S COUNTY

MAP KEY	FACILITY	TYPE
B1 -	Carroll Manor	Nursing Home
B2 -	Clinton Convalescent Center	Nursing Home
B3 -	Ft. Washington Rehab Center	Nursing Home
B4 -	Greater Laurel Nursing Home	Nursing Home
B5 -	Greenbelt Nursing Center	Nursing Home
B6 -	Hillhaven Nursing Home	Nursing Home
B7 -	Hyattsville Manor	Nursing Home
B8 -	Madison Manor Nursing Home	Nursing Home
B9 -	Magnolia Gardens Nursing Home	Nursing Home
B10 -	Manor Care - Largo	Nursing Home
B11 -	Pres. Woods Health Care	Nursing Home
B12 -	Regency Health Services	Nursing Home
B13 -	Sacred Heart Home	Nursing Home
B14 -	G.N. Spellman	Nursing Home
B15 -	Villa Rosa Nursing Home	Nursing Home
B16 -	Greater Laurel Beltsville Hospital Center	Nursing Home
B17 -	Reality House	Nursing Home
B18 -	St. Lukes Institute	Nursing Home
B19 -	Groomes Rest Home	Nursing Home
B20 -	Paint Branch	Nursing Home
B21 -	Edgemeade of MD	Nursing Home
B22 -	Regional Resource Center	Nursing Home
C1 -	AMI DRS Hospital of PG County	Hospital
C2 -	Clinton Community Hospital	Hospital
C3 -	Greater Laurel Beltsville Hospital	Hospital
C4 -	Eugene Leland Memorial Hospital	Hospital
C5 -*	Prince Georges General Hospital	Hospital
C6 -*	So. MD Hospital Center	Hospital
C7 -	Gladys N. Spellman Chr. Dis. Hospital	Hospital

* Shock Trauma Center

TABLE 3-13

INSTITUTIONS, MEDICAL FACILITIES, AND TRAILER PARKS
QUEEN ANNE'S COUNTY

MAP KEY	FACILITY	TYPE
B1 -	Meridian Nursing Center	Nursing Home
B2 -	Kitty's Domiciliary Home	Nursing Home
D1 -	Eastern Pre-Release Center	Prison
D2 -	County Jail	Prison
E1 -	Hocks Mobile Home Park	Trailer Park
E2 -	Trailer Park	Trailer Park
E3 -	Trailer Park	Trailer Park
E4 -	Trailer Park	Trailer Park
E5 -	Trailer Park	Trailer Park
E6 -	Trailer Park	Trailer Park

TABLE 3-14

INSTITUTIONS, MEDICAL FACILITIES, AND TRAILER PARKS
ST. MARY'S COUNTY

MAP KEY	FACILITY	TYPE
B1 -	Amber House	Nursing Home
B2 -	St Mary's Nursing Home	Nursing Home
B3 -	Charlotte Hall Veterans Home	Nursing Home
C1 -	St Mary's Hospital	Hospital
E1 -	California Trailer Park	Trailer Park
E2 -	Friendly Mobile Manor	Trailer Park
E3 -	Hills Trailer Park	Trailer Park
E4 -	Lord Calvert Trailer Park	Trailer Park
E5 -	National Motor Home Park	Trailer Park
E6 -	Sherlock Motor Home Estates	Trailer Park
E7 -	Suburban Motor Home Estates	Trailer Park

TABLE 3-15

INSTITUTIONS, MEDICAL FACILITIES, AND TRAILER PARKS
SOMERSET COUNTY

MAP KEY	FACILITY	TYPE
B1	- Manokin Manor	Nursing Home
B2	- Alice Byrd Tawes Nursing Home	Nursing Home
C1	- Edward W. McCready Memorial Hospital	Hospital
D1	- Eastern Correctional Institution	Prison
D2	- Somerset Co. Detention Center	Jail

TABLE 3-16

INSTITUTIONS, MEDICAL FACILITIES, AND TRAILER PARKS
TALBOT COUNTY

MAP KEY	FACILITY	TYPE
B1 -	William Hill Manor	Nursing Home
B2 -	Meridian Nursing Center	Nursing Home
B3 -	Dixon House	Nursing Home
B4 -	Chesapeake Center	Nursing Home
C1 -	Memorial Hospital at Easton	Hospital
C2 -	Idlewild Diagnostic Center	Medical Ctr
C3 -	Idlewild Digestive Disorders Ctr	Medical Ctr
C4 -	Regional Cancer Center	Medical Ctr
C5 -	Dialysis Center	Medical Ctr
C6 -	Renal Treatment Center	Medical Ctr
C7 -	Chesapeake Head Injury Center	Medical Ctr
D1 -	Talbot Co. Detention Center	Prison
E1 -	Foster's Trailer Park	Trailer Park
E2 -	Hyde Park Trailer Park	Trailer Park
E3 -	Talbot Motor Home Park	Trailer Park
E4 -	Swan Haven Trailer Park	Trailer Park
E5 -	Scott's Trailer Park	Trailer Park
E6 -	Tall Oaks Trailer Park	Trailer Park

TABLE 3-17

INSTITUTIONS, MEDICAL FACILITIES, AND TRAILER PARKS
WICOMICO COUNTY

MAP KEY	FACILITY	TYPE
B1 -	Deer's Head Center	Nursing Home
B2 -	Tiver Walk Manor	Nursing Home
B3 -	Salisbury Nursing Home	Nursing Home
B4 -	Wicomico Nursing Home	Nursing Home
B5 -	Hudson, Willis W. Center	Nursing Home
B6 -	John B. Parsons Sal Home for Aged	Nursing Home
B7 -	Holly Center	Nursing Home
C1 -*	Peninsula General Hospital	Hospital
C2 -	Deer's Head Center	Hospital
D1 -	Poplar Hill Pre-Release Unit	Prison
E1 -	Oak Terrace Trailer Park	Trailer Park
E2 -	Naylor Mill Village	Trailer Park
E3 -	Cedarhurst Village Trailer Park	Trailer Park
E4 -	Twin River Trailer Park	Trailer Park

* Shock Trauma Center

TABLE 3-18

INSTITUTIONS, MEDICAL FACILITIES, AND TRAILER PARKS WORCESTER COUNTY

MAP KEY	FACILITY	TYPE
B1 -	Berlin Nursing Home	Nursing Home
B2 -	Harrison House	Nursing Home
B3 -	Hartley Hall	Nursing Home
E1 -	Albatross Mobile Home Park	Trailer Park
E2 -	Trailer Park	Trailer Park
E3 -	Silver Lake Mobile Home Park	Trailer Park
E4 -	Green Ridge Mobile Home Park	Trailer Park
E5 -	Morris Mobile Home Park	Trailer Park
E6 -	Sea Isle Mobile Home Park	Trailer Park
E7 -	Trailer Park	Trailer Park
E8 -	Trailer Park	Trailer Park
E9 -	Trailer Park	Trailer Park
E10 -	Eagle Nest Mobile Home Park	Trailer Park
E11 -	Lake Haven Mobile Home Park	Trailer Park
E12 -	Montego Bay Trailer Park	Trailer Park

TABLE 3-19

INSTITUTIONS, MEDICAL FACILITIES, AND TRAILER PARKS OCEAN CITY

MAP KEY	FACILITY	TYPE
E1 -	Isle of Wight Trailer Park	Trailer Park
E2 -	Sundowner Trailer Park	Trailer Park
E3 -	Ocean City Travel Park	Trailer Park
E4 -	Warrens Trailer Park	Trailer Park

CHAPTER FOUR

BEHAVIORAL ANALYSIS

Purpose

The behavioral analysis is intended to provide reliable estimates of how the public in the study area will respond to a variety of hurricane threats. These estimates include the percentages of persons in specific locations that can be expected to evacuate, when they will evacuate relative to an evacuation advisory, where they will go for shelter, or additional behavioral data which were utilized in conducting other analyses for the study.

Objectives

The major objective of the Maryland Hurricane Evacuation Study behavioral analysis was to provide public evacuee response data for use in the shelter and transportation analyses, and to provide guidance in emergency decision-making and public awareness efforts. The specific objectives of the behavioral analysis were to determine the following:

a. The percentage of the affected and non-affected population that will evacuate under a range of hurricane threat situations or in response to evacuation advisories. The term "affected population" refers to those persons residing near the coastline, the shorelines of estuaries, or in areas of low elevation near those locations that are subject to the hazards of flooding. The affected population also includes those persons residing in mobile homes or substandard housing which may be at risk from the winds associated with a hurricane.

The term "non-affected population" refers to those individuals who are not threatened by storm surge or freshwater flooding and have substantial housing affording protection against winds of intensities expected to occur during a hurricane. It is known that a number of these individuals evacuate along with the affected population and contribute to the evacuating traffic and shelter demand during a hurricane threat.

b. When the evacuating population will leave in relation to an evacuation advisory given by local officials or other persons in authority.

c. The number of vehicles that the evacuating population will use during a hurricane evacuation.

d. The percentage of the total number of evacuating vehicles which may be towing boats, camper trailers, or other vehicular equipment.

e. The probable destinations of the evacuating households. This analysis determines the percentages of the total number of evacuees going to local public shelters, staying locally with friends or relatives, staying locally in a hotel/motel, or leaving the county for out-of-region destinations.

f. How the threatened population will respond based upon forecasts of hurricane intensity, probability, or other information provided during hurricane emergency.

g. The evacuation responses of tourists.

Data Sources

Several data sources were utilized for the behavioral analysis. These data sources include the following:

a. Sample Surveys. Telephone surveys were conducted with area residents to investigate likely evacuation responses under a variety of hurricane threat situations. The interview questions, shown in Appendix C, included queries concerning actual responses during Hurricane Gloria in 1985. The purpose of the sample surveys was to provide a basis for comparing responses obtained in Maryland with those obtained elsewhere and to provide a baseline from which response forecasts could be made.

Questions were asked of 100 residents in each of the following four geographical regions:

1) East: Ocean City Area
2) South: Crisfield Area
3) North: Denton Area
4) West: Anne Arundel County Area

The four geographical regions consist of the following counties in the Maryland Hurricane Evacuation Study:

East:	South:	North:	West:
Ocean City	Dorchester	Caroline	Anne Arundel
Wicomico	Somerset	Cecil	Baltimore City
Worcester		Harford	Baltimore County
		Kent	Calvert
		Queen Anne's	Charles
		Talbot	Prince George's
			St. Mary's

b. Hypothetical Responses from Other Areas. Several thousand interviews, comparable to those conducted as part of this study, have been conducted as parts of hurricane evacuation studies in other areas. Those studies were reviewed, and generalizations about their findings were included for comparison.

c. Post-Hurricane Response Studies. Post-hurricane response studies, many of which were conducted in the Gulf Coast area, were the most heavily utilized source of response data. These data are considered to be the most reliable indications of what people are most likely to do in future hurricane threats. The character and extent of these studies is large enough that a number of clear conclusions can be drawn about behavioral tendencies in a variety of hurricane threat situations. Although the studies show social variations from place to place, there are greater variations in public responses between differing hurricane threats in the same location than there are between similar events in differing locations. Moreover, attempts to detect response differences along socioeconomic lines among residents of a given location have generally been inconclusive. These findings permit considerable confidence in applying conclusions drawn in one location to a similar situation in another area. The list of post-hurricane response studies utilized in the Maryland

Hurricane Evacuation Study is provided in the reference section at the end of the main report.

Analysis Results

a. General. The following paragraphs address each of the specific objectives established for the behavioral analysis and present generalized results for each objective. More detailed results are contained in Appendix C, Behavioral Analysis.

b. Evacuation Participation Rates. Evacuation participation rates refer to the percentages of residents in high-, moderate-, and low-risk areas who can be expected to evacuate under various hurricane threats. Post-hurricane response studies indicate that a great amount of variation has occurred in evacuation participation from place to place in the same event, as well as from storm to storm in the same location. However, generalizations can be drawn from the existing data from historic storms, as well as from the sample surveys conducted for the study.

The behavioral analysis indicates that in the higher risk areas near the Maryland coastline or the Chesapeake Bay shoreline, 90 to 95 percent of those residents living in mobile homes can be expected to evacuate if they are strongly advised to do so by local officials. In those neighborhoods where residents live in housing other than mobile homes, 85 to 90 percent of the residents can be expected to evacuate, given the same advisory.

The participation rates of residents of moderate-risk areas are usually somewhat lower than those of high-risk areas and exhibit greater variation. Moderate-risk areas are those that are located some distance inland but are vulnerable to storm surge inundation under certain hurricane intensities. It is expected that 95 percent of mobile home residents will evacuate during a severe storm, while only 75 percent would evacuate during a minor hurricane. For those residents living in more substantial housing, 80 percent can be expected to evacuate during a severe storm, while only 40 percent would be expected to do so during a minor storm.

Those residents living several miles inland are located in low-risk areas, and their evacuation participation rates are much lower than those of residents living in higher risk areas. It is expected that more than 85 percent of mobile home residents will evacuate during a severe storm, while only 65 percent would evacuate during a minor hurricane. For those residents living in housing other than mobile homes, 20 to 30 percent can be expected to evacuate depending upon the severity of the storm.

c. Evacuee Response Rates. Evacuee response rates refer to the rate of evacuation by the threatened population and when the evacuating residents will leave relative to a given evacuation advisory. These rates are expressed as cumulative percentages of the total number of evacuees departing at time intervals before and after an evacuation advisory. Evacuation response rates for Hurricane Gloria are shown graphically as evacuation response curves in Appendix C, Behavioral Analysis. Actual response curves of evacuations from past storms outside of Maryland are also discussed in Appendix C.

Post-hurricane response studies show a diversity of slopes and shapes inherent in the response curves. This diversity can be primarily attributed to factors such as action by local officials, severity of the threatening hurricane, residents' perception of the probability of the hurricane striking their location, and the evacuation difficulties for their location. The primary factor consistent with most of the historic response curves is the sharp increase in evacuation response following the advice of local officials to evacuate. These increases in evacuation response following local advisements or orders show consistency regardless of location; relative magnitude of threat; or information previously furnished to the threatened population in the form of hurricane watches, warnings, or other meteorological information. For further information on evacuee response rates, see Chapter 6, Transportation Analysis Input Assumptions.

d. Vehicle Use. The percentages of vehicle use assumed for the Maryland Hurricane Evacuation Study were developed partly from the telephone sample surveys conducted as a part of the study. The final assumptions also took into account hypothetical responses, as well as actual percentages from the Hurricane Gloria evacuation.

The survey results indicate that persons living in the high-risk areas will utilize a greater percentage of the vehicles available to them than those residing in less vulnerable locations. Historically, 65 to 75 percent of available vehicles are used during evacuations. The Maryland survey results indicated that 71 percent of the available vehicles were used in areas near the coastline on the Eastern Shore. However, only 49 percent of the available vehicles were used in Anne Arundel County. This figure is likely to be low due to the fact that residents did not have a great deal of warning time to prepare for evacuation; thus, fewer vehicles were able to be taken. For planning purposes it would be prudent to assume that between 70 and 75 percent of all available vehicles will be used in most evacuations.

e. Destinations of Evacuating Households. The destinations or types of refuge most commonly utilized by the evacuating population include local public shelter facilities, local friends or relatives, local hotels/motels, or out-of-county locations. Significant variation in the percentages of persons utilizing various types of refuge can occur. Historically, this has occurred from storm to storm as well as from location to location. The circumstances prevailing in Maryland during Gloria illustrate this point and are described below.

In general, low income residents tend to use public shelters more than other groups, and this was true during Gloria in Crisfield, Maryland, where a total of 32 percent of the evacuees used public shelters. Surprisingly, 49 percent of the evacuees in Anne Arundel County, which is a relatively affluent area, used public shelter. This high shelter use can be explained, in part, by the fact that Anne Arundel residents evacuated much later in the evening and were unable to make arrangements with friends, relatives, or motels. Late night evacuation tends to create a sense of urgency, thus, maximizing shelter use.

Residents of high-risk areas, such as Ocean City, tend to respond sooner to evacuation recommendations, and they generally travel farther than residents in lower risk areas. In addition, beach residents often have higher incomes than residents in other areas, and they choose to stay in motels rather than public shelters if other arrangements cannot be made. The fact that only 14 percent of the Ocean City residents went to public shelters during Gloria supports these general assumptions.

Table 4-1 presents projections of normal shelter demand for residents living in various risk areas and in various income categories. These figures should be doubled during late, urgent evacuations, as this type of evacuation is not generally a function of location.

The actions of local officials can greatly influence the sheltering rates within a county. If, for example, public shelters are opened early and advertised, the public shelter use rates will most likely be significantly higher than for areas where the public is strongly advised to leave the county or where shelter locations and availability are not widely advertised.

TABLE 4-1

EXPECTED SHELTER DEMAND

	Risk Area		
Income	High	Moderate	Low
High	5%	10%	10%
Medium	15%	20%	25%
Low	-	40%	40%

f. Evacuee Response Based Upon Hurricane Intensity and Probability. A study addressing residents' use of probability information was conducted in the fall of 1984 at Wrightsville Beach, North Carolina. During that study, residents were presented with several hypothetical hurricane threat scenarios described in terms of severity, location of the storm, whether a hurricane watch or warning was in effect, and whether officials had advised or ordered evacuation. The respondents were asked to evaluate their probable actions for each of the scenarios. A second sample of residents was presented the same threats as the first, but with the probability information added. Thus, the responses of the two groups could be compared.

The results of this study indicate that the public understands and will utilize the probability information in their evacuation response. However, the most heavily relied upon source of information in evacuation decision-making by the general public is advice from local officials.

g. Evacuation Response of Vacationers. The major tourist area within the Maryland Hurricane Evacuation Study area is Ocean City. Based upon available information, 42 percent of the vacationers there at any given time live elsewhere in Maryland. Approximately 22 percent of the remaining visitors live in Pennsylvania, and 10 percent live in Virginia. Most of the visitors arrive in Ocean City in their own cars or campers and remain in the area for less than a week. Thus, three-fourths of the visitors are able to return home within a few hours in the event of a hurricane threat. In general, vacationers are not reluctant to evacuate their lodging or campground when advised, even though they have prepaid for their accommodations.

Beach vacationers generally attempt to avoid cloudy, rainy weather, and so they can be expected to leave an area during a hurricane threat without necessarily hearing of an official evacuation notice. In those cases where visitors have more than a few days remaining in their vacations, they can be expected to return to the beach after the hurricane threat has passed. Table 4-2 outlines the planning assumptions which are recommended for the Ocean City area.

TABLE 4-2

PLANNING ASSUMPTIONS FOR VACATIONERS AT OCEAN CITY

Evacuation Rates:	95% in severe storms 85% in weaker storms 50% in absence of evacuation notice if weather worsens
Evacuation Timing:	Generally same as for residents, but earlier if weather worsens.
Leaving County:	90% in severe storms (except in last minute evacuations) 70% in weaker storms, if space is available locally
Public Shelters:	< 5% in severe storms (except in last minute evacuation) >15% in weaker storms

Note: Vacationers are frequently influenced by information received from hotel/motel management. This is particularly true of RV parks.

CHAPTER FIVE

SHELTER ANALYSIS

Purpose

The shelter analysis serves two primary purposes. The most apparent use of the shelter analysis data is to develop the number of evacuees who will seek public shelter (shelter demand) within each county and to determine the number of shelter spaces available for those evacuees. This is the public shelter demand/capacity analysis. Total shelter capacity for each county is subject to change with the availability of suitable facilities.

The second, and less apparent, purpose of the shelter analysis is to provide information for use in determining evacuation clearance times in the transportation analysis. A thorough discussion of the methodology involved in the determination of these times is found in Chapter 6.

The shelter analysis consists of quantifying shelter demand, and inventories and capacities of shelters, within the Maryland Hurricane Evacuation Study area. Data developed in the hazards, vulnerability, and behavioral analyses were used to conduct the shelter analysis.

Shelter Analysis

a. General. The counties in Maryland operate their public shelters according to procedures which are unique to each individual county. In some cases the shelters may be operated by the American Red Cross, while in other instances they may be opened and operated by an appointed local official. In all cases, shelter operations and standards are similar for all counties, and each county coordinates their shelter activities with the Maryland Emergency Management Agency.

After reviewing the hurricane surge and inundation information developed in the hazards analysis and vulnerability analysis, some predesignated shelters were eliminated from eligibility during hurricane emergencies because of safety concerns. Some of those shelters were located within inundation zones, while others lay above expected flood elevations but could be rendered inaccessible by roadway inundation from storm surge. It is from the remaining group of shelters that total county capacities and evacuation clearance times were calculated. No attempt has been made to assess the vulnerability of any public shelter to the effects of winds from hurricanes.

b. Shelter Inventories and Capacities. Tables 5-1 through 5-18, located at the end of this chapter, list American Red Cross and locally-operated public shelters and capacities for each county within the study area. The shelter capacities were furnished by the Emergency Management Coordinators for each of the study area localities. The "map key" on these tables corresponds to the locations of the public shelters as shown for each county on the inundation maps in Appendix A.

Public Shelter Demand/Capacity

a. General. The results of the behavioral analysis conducted for the Maryland Hurricane Evacuation Study were used in determining the shelter demand for a variety of hurricane scenarios. The shelter capacities used in the analysis were developed by State and local officials.

b. Public Shelter Demand/Capacity Analysis. The results of the public shelter demand/capacity analysis are shown in Table 5-19. The table contains the total public shelter capacity within each Eastern Shore county and the number of evacuees seeking public shelter during each evacuation scenario. Evacuation scenarios are defined for each county in Chapter 6, Table 6-2. For those counties where seasonal occupancy varies appreciably, shelter demand is given as a range based on that variation. The analysis assumes an adequate warning period for an approaching hurricane and sufficient public knowledge concerning the locations and availability of public shelter facilities. Other assumptions used in developing the total number of evacuees and public shelter demand are as follows:

(1) One hundred percent of the affected population will evacuate.

(2) One to five percent (depending on storm intensity) of non-affected population will evacuate.

(3) Persons living in highly vulnerable locations, especially on a shoreline, will utilize public shelter facilities at rates from five to fifteen percent of the total number of evacuees from those locations, depending on the county and the season of the year.

(4) Persons living in moderately vulnerable locations will utilize public shelter facilities at a rate of fifteen percent of the total number of evacuees from those locations.

(5) Twenty to forty percent of the mobile home residents and persons evacuating from areas of low vulnerability will utilize public shelter facilities, depending upon the county.

(6) Approximately five to ten percent of vacationers will seek public shelter, depending on the county.

TABLE 5-1

PUBLIC SHELTER FACILITIES
ANNE ARUNDEL COUNTY

MAP KEY	FACILITY	CAPACITY
A1 -	Bates Middle School	300
A2 -	Broadneck Sr HS	500
A3 -	Annapolis Middle School	300
A4 -	Central Middle School	420
A5 -	Chesapeake Middle School	600
A6 -	Chesapeake Sr HS	800
A7 -	Meade Sr HS	800
A8 -	Glen Burnie Sr HS	800
A9 -	Severna Park HS	800
A10 -	Anne Arundel Com College	1000
A11 -	Old Mill Sr HS	1000
A12 -	Severna Park Middle School	350
A13 -	South River Sr HS	600
A14 -	Arundel Sr HS	700
A15 -	Southern Middle School	400
A16 -	MacArthur Middle School	500
A17 -	Southern Sr HS	400
A18 -	Andover Sr HS	350
A19 -	Annapolis Sr HS	850
A20 -	Brooklyn Park Sr HS	420
Total		11,920

TABLE 5-2

PUBLIC SHELTER FACILITIES
BALTIMORE CITY

MAP KEY	FACILITY	CAPACITY
A1 -	Margaret Brent Elem School	150
A2 -	Mt. Royal Elem School	150
A3 -	Dept of Education	500
A4 -	Joseph C. Briscoe Jr HS	200
A5 -	Harford Height Elem School	300
A6 -	Fort Worthington Elem School	200
A7 -	North Western Sr HS	200
A8 -	Pimlico Jr HS	200
A9 -	Wm. H. Lemmel Jr HS	200
A10 -	Chinguapin Middle School	200
A11 -	Poly-Western	400
A12 -	Clifton HS	300
A13 -	*	-
A14 -	Northeast Middle School	150
A15 -	Herring Run Jr HS	200
A16 -	Northern HS	250
A17 -	Hamilton Jr HS	100
A18 -	Dunbar HS	300
A19 -	Lombard Jr HS	150
A20 -	Patterson Park HS	300
A21 -	Southeast Middle School	250
A22 -	Southern HS	200
A23 -	Benjamin Franklin Jr HS	125
A24 -	Cherry Hill Jr HS	200
A25 -	Francis Scott Key	100
A26 -	Walbrook HS	200
A27 -	Edmondson HS	200
A28 -	Southwestern HS	200
A29 -	West Baltimore Middle School	200
A30 -	Gwynns Falls Jr HS	200
A31 -	Douglass HS	200
A32 -	Calverton Jr HS	200
Total		6725

* Note: Shelter Closed.

TABLE 5-3

PUBLIC SHELTER FACILITIES
BALTIMORE COUNTY

MAP KEY	FACILITY	CAPACITY
A1 -	Arbutus Jr HS	160
A2 -	Catonsville Jr HS	155
A3 -	Catonsville Sr HS	250
A4 -	Chesapeake Sr HS	335
A5 -	Cockeysville Jr HS	150
A6 -	Deep Creek Jr HS	180
A7 -	Deer Park Jr HS	170
A8 -	Dulaney Sr HS	335
A9 -	Dumbarton Jr HS	160
A10 -	Dundalk Middle School	125
A11 -	Dundalk Sr HS	300
A12 -	Eastern Vocational School	185
A13 -	Franklin Jr HS	170
A14 -	Franklin Sr HS	300
A15 -	Gen. John Stricker Jr HS	195
A16 -	Golden Ring Jr HS	175
A17 -	Hereford Jr-Sr HS	150
A18 -	Holabird Jr HS	150
A19 -	Johnnycake Jr HS	140
A20 -	Kenwood Sr HS	255
A21 -	Lansdowne Middle School	170
A22 -	Lansdowne Sr HS	150
A23 -	Loch Raven Jr HS	175
A24 -	Loch Raven Sr HS	305
A25 -	Middle River Jr HS	160
A26 -	Milford Mill Sr HS	240
A27 -	Old Court Jr HS	175
A28 -	Overlea Sr HS	305
A29 -	Owings Mills Sr HS	150
A30 -	Parkville Jr HS	160
A31 -	Parkville Sr HS	300
A32 -	Patapsco Sr HS	310
A33 -	Perry Hall Jr HS	170
A34 -	Perry Hall Sr HS	295
A35 -	Pikesville Jr HS	165
A36 -	Pikesville Sr HS	310
A37 -	Pine Grove Jr HS	150
A38 -	Randallstown Sr HS	300
A39 -	Ridgeley Jr HS	160
A40 -	Sparrows Pt. Middle-Sr HS	145
A41 -	Stemmers Run Jr HS	125
A42 -	Towson Sr HS	245
A43 -	Woodlawn Jr HS	180
A44 -	Woodlawn Sr HS	305
Total		9190

TABLE 5-4

PUBLIC SHELTER FACILITIES
CALVERT COUNTY

MAP KEY	FACILITY	CAPACITY
A1	Appeal School	200
A2	Calvert Sr HS	600
A3	Huntingtown Elem School	300
A4	Beach Elem School	300
A5	Northern Middle School	450
A6	Northern HS	900
A7	Mt. Harmony Elem School	350
A8	Calvert Middle School	300
A9	Mt. Hope Com. Ctr	75
A10	Mutual Elem School	250
A11	Southern Middle School	400
A12	Sunderland Elem School	250
Total		4375

TABLE 5-5

PUBLIC SHELTER FACILITIES
CAROLINE COUNTY

MAP KEY	FACILITY	CAPACITY
A1	Greensboro Elementary School	500
A2	Ridgely Elementary School	300
A3	Denton Elementary School	550
A4	Preston Elementary School	400
A5	Federalsburg Elementary School	500
A6	Riverview Middle School	550
A7	Col. Richardson Middle School	500
A8	North Caroline High School	600
A9	Col. Richardson High School	600
A10	Caroline Cty. Vocational Ctr.	150
Total		4650

TABLE 5-6
PUBLIC SHELTER FACILITIES
CECIL COUNTY

MAP KEY	FACILITY	CAPACITY
A1 -	Kenmore Elem School	238
A2 -	Cecil Manner School	207
A3 -	Cecil Voc. Tech	2312
A4 -	Bay View Elem School	526
A5 -	Charlestown Elem School	305
A6 -	Northeast HS	1213
A7 -	Northeast Fire Co.	201
A8 -	U.S. Post Office	126
A9 -	Rising Sun Senior Home	2754
A10 -	Conowingo Elem School	157
A11 -	Calvert School	338
Total		8377

TABLE 5-7
PUBLIC SHELTER FACILITIES
CHARLES COUNTY

MAP KEY	FACILITY	CAPACITY
A1 -	Walter J. Mitchell Elem School	1125
A2 -	*	-
A3 -	Charles Co. Library	424
A4 -	Co. Court House	1558
A5 -	M. Sommers Shp Bldg	180
A6 -	Charles Co. Brd of Educ	256
A7 -	U.S. Post Office	1112
A8 -	La Plata VFD	222
A9 -	Charles Co. Sheriff	284
A10 -	Old La Plata HS	1000
A11 -	MD Dept H M N	260
A12 -	M M Sommers Jr HS	1073
A13 -	Wayside Elem School	150
A14 -	Piccowaxen Middle School	1848
Total		9492

* Note: Shelter Closed.

TABLE 5-8

PUBLIC SHELTER FACILITIES
DORCHESTER COUNTY

MAP KEY	FACILITY	CAPACITY
A1 -	Cambridge-South Dorchester HS	1300
A2 -	Hurlock Elem School	425
A3 -	Vienna Elem School	272
A4 -	Warwick Elem School	385
A5 -	North Dorchester Mid School	600
A6 -	Eastern Shore Hosp Ctr	3300
A7 -	*	-
A8 -	Cambridge P.O. (Basement)	940
A9 -	Chesapeake College Satellite	150
A10 -	YMCA	1000
A11 -	Maces Lane Middle School	600
A12 -	Sandy Hill Elem School	500
A13 -	Maple Elem School	500
A14 -	St. Clair Elem School	300
A15 -	Vo Tech	200
A16 -	Bd. of Educ. (Gym)	200
A17 -	North Dorchester HS	400
A18 -	South Dorchester Elem School	250
Total		10,622

* Note: Shelter Closed.

TABLE 5-9
PUBLIC SHELTER FACILITIES
HARFORD COUNTY

MAP KEY	FACILITY	CAPACITY
A1 -	Aberdeen HS, North Bldg	572
A2 -	Aberdeen HS, South Bldg	880
A3 -	Halls Cross Roads Elem School	375
A4 -	Aberdeen Middle School	1061
A5 -	Hillsdale Elem School	275
A6 -	Bakersfield Elem School	287
A7 -	Havre de Grace Elem School	375
A8 -	Havre de Grace Middle School	540
A9 -	Havre de Grace HS	677
A10 -	Oakington Elem School	500
A11 -	Wm. Pacal Old Post Road Elem Sch	612
A12 -	Edgewood Middle School	980
A13 -	Edgewood HS	935
A14 -	Deerfield Elem School	325
A15 -	Joppatowne HS	751
A16 -	Magnolia Elem School	300
A17 -	Magnolia Middle School	780
A18 -	Riverside Elem School	312
A19 -	Fallston HS	1070
A20 -	Youth's Benefit School	550
A21 -	John Carroll HS	792
A22 -	Bel Air HS	921
A23 -	Bel Air Middle School	673
A24 -	Harford Christian School	376
A25 -	North Harford HS	877
A26 -	North Harford Middle School	878
Total		16,674

TABLE 5-10
PUBLIC SHELTER FACILITIES
KENT COUNTY

MAP KEY	FACILITY	CAPACITY
A1 -	Kent Co. HS	400
A2 -	Worten Elem School	125
A3 -	Galena Elem School	161
A4 -	Millington Elem School	242
A5 -	Chestertown Elem School	243
A6 -	Chestertown Middle School	255
A7 -	Rock Hall Elem School	172
A8 -	Rock Hall Middle School	144
A9 -	Kent School	25
A10 -	Chestertown Christian Acad.	50
A11 -	Washington College	200
A12 -	*	-
A13 -	*	-
Total		2217

* Note: Shelter Closed.

TABLE 5-11
PUBLIC SHELTER FACILITIES
PRINCE GEORGE'S COUNTY

MAP KEY	FACILITY	CAPACITY
A1	- University of Maryland	44,266
A2	- P. G. Community College	11,244
A3	- Bowie State College	2750
A4	- Columbia Union College	820
A5	- Washington Bible College	600
A6	- Capitol Institute of Technology	0
A7	- Diebel Institute of America	222
A8	- Adelphi Elementary Sch	494
A9	- Allenwood Elementary School	406
A10	- Andrew Jackson Middle School	862
A11	- Apple Grove Elementary School	572
A12	- Ardmore Elementary School	408
A13	- Arrowhead Elementary School	534
A14	- Ascension Lutheran School	217
A15	- Avalon Elementary School	338
A16	- Baden Elementary School	362
A17	- Barnaby Manor Elementary School	361
A18	- Beacon Heights Elementary School	361
A19	- Beltsville Elementary School	574
A20	- Benjamin D. Foulois Middle School	495
A21	- Benjamin Stoddert Middle School	611
A22	- Benjamin Tasker Middle School	768
A23	- Berkshire Elementary School	601
A24	- Bishop McNamara High School	718
A25	- Bladensburg Elementary School	694
A26	- Bladensburg High School	2035
A27	- Bond Mill Elementary School	566
A28	- Bowie High School	2949
A29	- Bradbury Heights Elementary School	451
A30	- Brandywine Elementary School	580
A31	- Buck Lodge Middle School	679
A32	- Calverton Elementary School	648
A33	- Capitol Heights Elementary School	339
A34	- Carmody Hills Elementary School	370
A35	- Carole Highlands Elementary School	439
A36	- Carrollton Elementary School	505
A37	- Catherine T. Reed Elementary School	361
A38	- Central High School	1266
A39	- Chapel Forge Elementary School	312
A40	- Charles Carroll Middle School	948
A41	- Cherokee Lane Elementary School	404
A42	- Cheverly-Tuxedo Elementary School	430
A43	- Chillum Elementary School	569
A44	- Clinton Grove Elementary School	485
A45	- Columbia Park Elementary School	604
A46	- Concordia Lutheran School	300
A47	- Cooper Lane Elementary	436

TABLE 5-11 (CONTINUED)

MAP KEY	FACILITY	CAPACITY
A48	- Croom Vocational School	111
A49	- Crossland High School	1896
A50	- De Matha High School	985
A51	- Deerfield Run Elementary School	466
A52	- District Heights Elementary School	489
A53	- Dodge Park Elementary School	531
A54	- Doswell E. Brooks Elementary School	498
A55	- DuVal High School	1994
A56	- Dwight D. Eisenhower Middle School	708
A57	- Edgar Allen Poe Elementary School	388
A58	- Eleanor Roosevelt High School	2665
A59	- Elizabeth Seaton High School	871
A60	- Eugene Burroughs Middle School	568
A61	- Fairmont Heights High School	1415
A62	- Flinstone Elementary School	371
A63	- Forest Heights Elemendary School	244
A64	- Forestville High School	1095
A65	- Fort Foote Elementary School	482
A66	- Fort Washington Forest Elem School	447
A67	- Francis Scott Key Middle School	950
A68	- Francis T. Evans Elementary School	621
A69	- Frederick Douglas High School	1369
A70	- Friendly High School	1968
A71	- G. Gardner Shugart Middle School	584
A72	- Gaywood Elementary School	570
A73	- Glassmanor Elementary School	337
A74	- Glenarden Woods Elementary School	308
A75	- Glenridge Elementary School	698
A76	- Green Valley Elementary School	478
A77	- Greenbelt Center Elementary School	597
A78	- Greenbelt Middle School	848
A79	- Gwynn Park High School	1372
A80	- Heather Hills Elementary School	310
A81	- Henry G. Ferguson Elementary School	359
A82	- High Bridge Elementary School	454
A83	- High Point High School	2890
A84	- Hillcrest Heights Elementary School	708
A85	- Hollywood Elementary School	525
A86	- Holly Redeemer School	264
A87	- Hyattsville Elementary School	576
A88	- Indian Queen Elementary School	367
A89	- J. Frank Dent Elementary School	2328
A90	- James H. Harrison Elementary School	409
A91	- James Madison Middle School	778
A92	- James McHenry Elementary School	364
A93	- James Ryder Randall Elem School	520
A94	- John Carroll Elementary School	438
A95	- John E. Howard Elementary School	628

TABLE 5-11 (CONTINUED)

MAP KEY	FACILITY	CAPACITY
A96	- John H. Bayne Elementary School	425
A97	- John Nevin Andrews School	325
A98	- Kenilworth Elementary School	617
A99	- Kenmoor Elementary School	481
A100	- Kenmoor Middle School	497
A101	- Kettering Elementary School	660
A102	- Kettering Middle School	615
A103	- La Reine High School	757
A104	- Lamont Elementary School	505
A105	- Langley Park-McCormick Elem School	641
A106	- Lanham Vocational School	88
A107	- Largo High School	2035
A108	- Laurel Elementary School	614
A109	- Laurel High School	1927
A110	- Lewisdale Elementary School	540
A111	- Longfields Elementary School	317
A112	- Lord Baltimore Middle School	788
A113	- Lyndon Hill Elementary School	360
A114	- Magnolia Elementary School	409
A115	- Marlton Elementary School	394
A116	- Martin Luther King Jr. Middle School	811
A117	- Mattaponi Elementary School	474
A118	- Matthew Henson Elementary School	348
A119	- Melwood Elementary School	620
A120	- Middleton Valley Elementary School	603
A121	- Montpelier Elementary School	407
A122	- Morningside Elementary School	437
A123	- Mt. Calvery Catholic School	565
A124	- Mount Rainer Elementary School	434
A125	- Nicholas Orem Middle School	869
A126	- North Forestville Elementary School	387
A127	- Northwestern High School	2358
A128	- Oakcrest Elementary School	440
A129	- Oaklands Elementary School	501
A130	- Our Lady of Borrows School	236
A131	- Overlook Elementary School	365
A132	- Owens Road Elementary School	368
A133	- Oxon Hill Elementary School	513
A134	- Oxon Hill High School	2586
A135	- Oxon Hill Middle School	957
A136	- Paint Branch Elementary School	387
A137	- Pallotti High School	450
A138	- Parkdale High School	2358
A139	- Patuxent Elementary School	295
A140	- Phylis E. Williams Elementary School	441
A141	- Pointer Ridge Elementary School	547
A142	- Potomac High School	1804
A143	- Potomac Landing Elementary School	588

TABLE 5-11 (CONTINUED)

MAP KEY	FACILITY	CAPACITY
A144	Princeton Elementary School	552
A145	Queen Ann School	325
A146	Regina High School	333
A147	Ridgecrest Elementary School	564
A148	Riverdale Baptist School	1080
A149	Riverdale Elementary School	697
A150	Robert Frost Elementary School	352
A151	Robert Goddard Middle School	674
A152	Rockledge Elementary School	456
A153	Robert B. Taney Middle School	673
A154	Rogers Heights Elementary School	464
A155	Rose Valley Elementary School	414
A156	St. Ambrose School	450
A157	St. Bernard's School	437
A158	St. Columbia R. C. School	298
A159	St. Donatils Parochial School	254
A160	St. Jerome's School	540
A161	St. Josephs Catholic School	264
A162	St. Margaret's School	270
A163	St. Mary's School of Piscataway	253
A164	St. Mary's of the Assumption School	343
A165	St. Philip's School	255
A166	Samuel Chase Elementary School	380
A167	Samuel Ogle Middle School	593
A168	Seabrook Elementary School	287
A169	Seat Pleasant Elementary School	442
A170	Shadyside Elementary School	355
A171	Skyline Elementary School	429
A172	Springhill Lake Elementary School	625
A173	Stephen Decatur Middle School	705
A174	Suitland High School	2128
A175	Surrattsville High School	1116
A176	Tayac Elementary School	473
A177	Templeton Elementary School	632
A178	Thomas Clabbet Elementary School	415
A179	Thomas G. Pullen Middle School	718
A180	Thomas Johnson Elementary School	805
A181	Thomas S. Stone Elementary School	655
A182	Tulip Grove Elementary School	374
A183	University Park Elementary School	472
A184	Valley View Elementary School	478
A185	Walden Woods Elementary School	464
A186	Walker Mill Middle School	498
A187	William Beames Elementary School	508
A188	William Paca Elementary School	336
A189	William Wirt Middle School	918
A190	Woodmore Elementary School	452
A191	Woodbridge Elementary School	323
A192	Yorktown Elementary School	316
Total		182,795

TABLE 5-12

PUBLIC SHELTER FACILITIES
QUEEN ANNE'S COUNTY

MAP KEY	FACILITY	CAPACITY
A1 -	United Com. Fire Dept Co. 9	50
A2 -	Kent Island Fire Dept Co. 1	50
A3 -	Kent Island Elem School	200
A4 -	Stevensville Middle School	300
A5 -	Grasonville Fire Dept Co. 2	50
A6 -	Grasonville Senior Ctr	100
A7 -	Grasonville Elem School	100
A8 -	Chestererwye Ctr	25
A9 -	Queenstown Fire Dept Co. 3	25
A10 -	Chesapeake College	800
A11 -	Goodwill Fire Dept Co. 4	100
A12 -	Queen Anne's Co. HS	600
A13 -	Kennard Annex Bldg	100
A14 -	Centreville Middle School	400
A15 -	Centreville Elem School	200
A16 -	Church Hill Fire Dept Co. 5	50
A17 -	Church Hill Elem School	100
A18 -	Sudlersville Fire Dept Co. 6	150
A19 -	Sudlersville Elem School	200
A20 -	Sudlersville Middle School	200
A21 -	Crumpton Fire Dept Co. 7	100
A22 -	Queen Anne-Hills Fire Co. 8	50
Total		3950

TABLE 5-13

PUBLIC SHELTER FACILITIES
ST. MARY'S COUNTY

MAP KEY	FACILITY	CAPACITY
A1 -	Anne Arundel Hall	621
A2 -	Baltimore Hall	583
A3 -	Caroline Hall	764
A4 -	Charles Hall	606
A5 -	Dorchester Hall	764
A6 -	Kent Hall	486
A7 -	Prince George's Hall	789
A8 -	Queen Anne Hall	764
A9 -	Calvert Hall	447
A10 -	Somerset Hall	1069
A11 -	Margaret Brent Hall	126
A12 -	Fine Arts Center	1698
A13 -	St. Mary's City Commsn	133
A14 -	Park Hall Elem School	100
A15 -	Carver Elem School	100
A16 -	Greenview Knolls Elem School	200
A17 -	Maintenance Bldg	101
A18 -	Ridge VFD	168
A19 -	Spring Ridge Middle School	1400
A20 -	Piney Point Elem School	596
A21 -	Banneker Elem School	161
A22 -	Medical Arts Bldg	533
A23 -	Leonardtown Middle School	990
A24 -	Leonardtown HS	1492
A25 -	St Mary's County Tech Ctr	1218
A26 -	County Health Dept Bldg	185
A27 -	St Mary's County Courthouse	561
A28 -	Dial Ctr CP Telephone Co	382
A29 -	Green Holly School	200
A30 -	Board of Educ	270
A31 -	St Mary's Co Govt Ctr	269
A32 -	Leonardtown Elem School	460
A33 -	City Vol Fire Dept	438
A34 -	CP Telephone	144
A35 -	State Dept of Employment	124
A36 -	Margaret Brent Middle School	2137
A37 -	Community Hall	187
A38 -	Great Mills HS	400
A39 -	Dynard Elem School	100
A40 -	Oakville Elem School	150
A41 -	Chopticon HS	300
Total		22,934

TABLE 5-14

PUBLIC SHELTER FACILITIES
SOMERSET COUNTY

MAP KEY	FACILITY	CAPACITY
A1	- Civic Center	198
A2	- Greenwood Elementary School	1049
A3	- Somerset County Office Complex	992
A4	- County Court House	311
A5	- Prince Anne Fire Dept.	124
A6	- Princess Anne Elementary School	671
A7	- Crisfield Post Office	278
A8	- Crisfield Elementary School	448
A9	- Crisfield Volunteer Fire Dept.	113
A10	- Woodson Middle School	301
A11	- Crisfield Elementary School #1	211
A12	- Crisfield High School	504
A13	- Marion Elementary School	697
A14	- *	-
A15	- Deal Island School	580
A16	- Nuttle Hall	488
A17	- Murphy Hall - Annex	903
A18	- Somerset Hall	330
A19	- Harford Hall	325
A20	- Trigg Hall	574
A21	- Maryland Hall	401
A22	- Somerset Jr., High School	1077
A23	- Phys Ed Bldg.	492
A24	- Wicomico Hall	371
A25	- Student Center	1018
A26	- Water Dining Hall	340
A27	- Douglas Library	792
A28	- Fitzgerald Perf Arts	717
A29	- Carver Hall	575
A30	- Washington High School	2456
A31	- Dormitory 6B	218
A32	- Dormitory 6A	218
A33	- Wilson Hall	228
A34	- G. W. Carver Hall	439
A35	- Student Union	786
Total		19,484

* Note: Shelter Closed.

TABLE 5-15
PUBLIC SHELTER FACILITIES
TALBOT COUNTY

MAP KEY	FACILITY	CAPACITY
A1 -	Christ Church Rectory	162
A2 -	Christ Church	361
A3 -	Church of the Brethren	313
A4 -	Country Club House	360
A5 -	County Building	646
A6 -	Easton Court House	318
A7 -	Talbot County Library	288
A8 -	Talbot County Jail	264
A9 -	Goose Pit Antique Store	45
A10 -	Easton Post Office	765
A11 -	Elk's Home	180
A12 -	First Baptist Church	358
A13 -	Masonic Building	1083
A14 -	Memorial Hospital	1411
A15 -	Murdoch Gardens	86
A16 -	Easton State Police	228
A17 -	St. Marks Methodist Church	565
A18 -	Talbot Bank of Easton	126
A19 -	Talbottown Ctr Stores of Easton	468
A20 -	Talbottown Ctr Prof. Bldg	1245
A21 -	Talbot County YMCA	580
A22 -	Talbot County Health Center	600
A23 -	Tidewater Inn	3368
A24 -	Historical Society	115
A25 -	I. O. O. F. Building	250
A26 -	Loyola Federal S & L	396
A27 -	Maryland National Bank	377
A28 -	Maryland National Bank Svc Ctr	20
A29 -	Christ Church	315
A30 -	Methodist Church	236
A31 -	Methodist Church	144
A32 -	St. Michael's Fire House	200
A33 -	Easton Fire House	325
A34 -	Cordova Fire House	200
A35 -	Trappe Fire House	100
A36 -	Oxford Fire House	100
A37 -	Tilghman Fire House	75
A38 -	Easton High School	509
A39 -	Easton Middle School	300
A40 -	Glenwood Elementary School	100
A41 -	Glenwood Intermediate School	176
A42 -	Mount Pleasant Elementary School	75
A43 -	St. Michael's High School	200
A44 -	St. Michael's Elem/Middle School	225
A45 -	Cordova Upper County School	75
A46 -	Cordova Elementary School	75

TABLE 5-15 (CONTINUED)

MAP KEY	FACILITY	CAPACITY
A47 -	White Marsh Elementary School	75
A48 -	County School	300
A49 -	St. Peter & Paul Elem/HS	300
A50 -	Tilghman Elem School	100
Total		19,183

TABLE 5-16

PUBLIC SHELTER FACILITIES
WICOMICO COUNTY

MAP KEY	FACILITY	CAPACITY
A1 -	Mardela H.S.A.	972
A2 -	Mardela Spring Fire House	219
A3 -	Mardela Elem School	786
A4 -	Mardela High Gym B	319
A5 -	Mardela High Gym C	360
A6 -	Mardela High Gym D	561
A7 -	Westside Elem School	467
A8 -	Elem School	517
A9 -	School Annex	320
A10 -	School Gym	249
A11 -	Glen Ave. Elem School	122
A12 -	E. Salisbury Elem School	712
A13 -	State Police Barrack E	102
A14 -	E. Salisbury Sch Wing A	140
A15 -	E. Salisbury Sch Wing B	140
A16 -	Beaver Run Sch Bldg 1	224
A17 -	Beaver Run Sch Bldg 2	317
A18 -	Beaver Run Sch Bldg 3	131
A19 -	Parkside HS	2601
A20 -	Glen Ave. Elem School	432
A21 -	YMCA	692
A22 -	Wor-Wic Tech Train. Ctr	219
A23 -	Fruitland Primary School	1225
A24 -	Deer's Head Ctr	2072
A25 -	Pemberton Elem School	730
A26 -	Chapel Deer's Ctr	318
A27 -	Wicomico Health Dept	382
A28 -	Salisbury Water Plant	193
A29 -	Blackwell Library	705
A30 -	Federal Bldg	277
A31 -	N. Salisbury School	730
A32 -	Pocomoke Hall	572
A33 -	Devilbiss Science Hall	1248
A34 -	Choptank Hall	1104
A35 -	Govt Office Bldg	872
A36 -	Prince St. School	314
A37 -	Woodbridge School	195
A38 -	MD Dept Nat Resources	168
A39 -	County Social Services	420
A40 -	MD Div of Labor	378
A41 -	Dept of Motor Vehicles	214
A42 -	Salisbury Elem Sch Annex	182
A43 -	Salisbury Elem Sch Annex	714
A44 -	N. Sal. Sch Mid. Wing	196
A45 -	Sharptown Elem School	561

TABLE 5-16 (CONTINUED)

MAP KEY - FACILITY	CAPACITY
A46 - Delmar Elem School	4499
A47 - Bennett Jr HS	2371
A48 - Bennett Sr HS	2417
A49 - Holoway Hall	3874
A50 - Wicomico Jr HS	1868
A51 - Wicomico Sr HS, Bldg 9	82
A52 - Manokin Hall	401
A53 - Wicomico Sr HS, Bldg 4	692
A54 - Wicomico Sr HS, Bldg 6	267
A55 - Wicomico Sr HS, Bldg 7	492
A56 - Wicomico Sr HS, Bldg 12	212
A57 - Wicomico Sr HS, Bldg 15	444
A58 - Wicomico Sr HS, Bldg 10	440
A59 - Nanticoke Hall	410
A60 - Health Care Ctr	1091
A61 - Chester Hall	280
A62 - Chesapeake Hall	1296
A63 - Musical Arts Ctr	199
A64 - Caruthers Hall	432
A65 - Phys Ed Bldg	2680
A66 - Wicomico Sr. High Admin	90
A67 - Wicomico Sr. High Gym	553
A68 - Wicomico Sr. High Audit	566
A69 - Dining Hall	580
A70 - Tawes Gym	432
A71 - Wicomico Jr HS, Bldg C	274
A72 - Wicomico Jr HS, Bldg B	424
A73 - Pinehurst Elem School	262
A74 - Board of Education	274
A75 - School	170
A76 - Westside Intermediate	377
A77 - Fruitland Inter. School	450
Total	53,271

TABLE 5-17

PUBLIC SHELTER FACILITIES
WORCESTER COUNTY

MAP KEY	FACILITY	CAPACITY
A1 -	Pocomoke Elem School	967
A2 -	Police Dept	296
A3 -	Pocomoke HS	1146
A4 -	Pocomoke Middle School	1760
A5 -	Stephen Decatur HS	1298
A6 -	Worcester Ctr HS	700
A7 -	County Library	293
A8 -	Fire House	143
A9 -	Berlin Fire Dept	266
A10 -	City Hall	192
A11 -	Buckingham Elem School	750
A12 -	CEC Vocational Bldg	490
A13 -	County Educ Ctr	1806
A14 -	O.C. Fire Dept	333
A15 -	O.C. City Hall	470
A16 -	O.C. Elem School	2249
Total		13,159

* Note: Shelter Closed.

TABLE 5-18

PUBLIC SHELTER FACILITIES
OCEAN CITY

MAP KEY	FACILITY	CAPACITY
A1 -	North Side Recreation Park	500
A2 -	Convention Center	2000
Total		2500

TABLE 5-19

PUBLIC SHELTER DEMAND/CAPACITY STATISTICS

COUNTY	SAFFIR-SIMPSON CATEGORY	MAXIMUM PUBLIC SHELTER DEMAND	SHELTER CAPACITY
Anne Arundel	1-2, low season	4,530	20,116
	1-2, high season	4,730	
	3-4, low season	5,845	
	3-4, high season	6,080	
Caroline	1-4	750	4,650
Dorchester	1	630	11,530
	2-3	790	
	4	1,465	
Kent	1-4	550	2,217
Queen Anne's	1-2	1,395	3,950
	3-4	2,290	
St. Mary's	1-4	3,465	21,384
Somerset	1	840	19,484
	2-3	990	
	4	1,175	
Talbot	1	1,085	18,483
	2-4	1,630	
Wicomico	1	1,100	53,271
	2-3	1,250	
	4	1,480	
Worcester (figures include Ocean City evacuees)	1-2, November	1,645	13,159
	1-2, shoulder weekend	5,180	
	1-2, summer weekday	7,200	
	1-2, summer weekend	11,250	
	3-4, November	2,640	
	3-4, shoulder weekend	7,000	
	3-4, summer weekday	9,495	
	3-4, summer weekend	19,420	
Ocean City	1-2, November	685	2,500
	1-2, shoulder weekend	4,480	
	1-2, summer weekday	6,175	
	1-2, summer weekend	10,175	
	3-4, November	1,010	
	3-4, shoulder weekend	5,330	
	3-4, summer weekday	7,800	
	3-4, summer weekend	12,740	

CHAPTER SIX

TRANSPORTATION ANALYSIS

Purpose

The purposes of the transportation analysis are to define the evacuation roadway network for each county within the study area, to evaluate traffic control measures for improved traffic flow, and to calculate the clearance times for a range of hurricane evacuation situations. Each clearance time results from a transportation engineering analysis performed under a specific set of assumptions. Factors that affect clearance time have been studied at length to determine those having the greatest influence. Sensitivity analyses were performed, and clearance times were calculated for each county by varying key input parameters. Those parameters included varying evacuation participation rates, response rates, and tourist occupancy.

As discussed in Chapters One and Three, this study is based upon the assumption that the evacuation clearance times for the Western Shore counties will be equal to the expected response times, which are discussed in Chapter Four. A complete transportation analysis of Anne Arundel and St. Mary's Counties, indicated that this assumption was correct. Thus, for the remaining Western Shore counties (Baltimore, Calvert, Charles, Cecil, Harford, Prince George's, and Baltimore City), no transportation analyses were performed. With the exception of Tables 6-1 and 6-5, the data presented in this chapter corresponds to the transportation analyses performed on Anne Arundel and St. Mary's Counties and the Eastern Shore counties of the study area.

Evacuation Travel Patterns

a. General. During a hurricane evacuation effort, a large number of vehicles must be moved across a road network in a relatively short period of time. As pointed out by the behavioral analysis, the number of evacuating vehicles will vary depending upon the intensity of the hurricane, the number of tourists remaining in the area, and certain behavioral response characteristics of the evacuating population.

Vehicles enter the road network at different times depending upon an individual evacuee's response to an evacuation advisory. Conversely, vehicles leave the roadway network depending upon both the planned destinations of evacuees and the availability of acceptable destinations such as public shelter facilities, hotel/motel units, and friends or relatives in non-vulnerable locations. Vehicles move across the roadway network from trip origin to destination at speeds limited by the roadway capacity, which is the relationship of the traffic loadings on the various roadway segments to the ability of the segments to handle those loadings.

b. Traffic Movements. The transportation analysis task initially identified the kinds of traffic movements that must be considered in the development of clearance times. Basic assumptions for the transportation analysis were then developed related to regional storm scenarios, population at risk, behavioral and socioeconomic characteristics, the roadway system, and traffic control. The transportation modeling methodology and a roadway system representation were developed for each county in the study area to facilitate development of clearance times. Traffic movement between Maryland and Delaware, as well as between Maryland and Virginia, were considered in the models for each county. Information and data related to the transportation analysis are presented in summary form in this chapter. The Transportation Analysis Model Support Document, Appendix D of this Technical Data Report, includes a detailed account of all transportation analysis modeling, methodologies, and findings. Traffic movements associated with hurricane evacuation have been identified for the purposes of this analysis by five general patterns:

(1) In-County Origins to In-County Destinations. Trips made from storm surge vulnerable areas, mobile home units, and areas subject to freshwater flooding from heavy rainfall in each county to destinations within the same county. Such destinations include public shelters, hotel/motel units, and friends and relatives in non-vulnerable locations.

(2) In-County Origins to Out-of-County Destinations. Trips that originate within a county but have destinations in other counties within the study area or outside the region entirely.

(3) Out-of-County Origins to In-County Destinations. Trips that originate from other counties within the region and have destinations within a particular county.

(4) Out-of-County Origins to Out-of-County Destinations. Trips passing through a county which originate outside the county and with destinations in another county in the region or outside the region entirely. This travel pattern is critical due to the effects of Ocean City evacuation traffic passing through Wicomico, Dorchester, Talbot and Queen Anne's Counties on U.S. 50. Traffic originating in Delaware and traveling to or through Caroline and Talbot Counties on Route 404 and on U.S. 50 in Queen Anne's County will also have a significant impact on the overall traffic flow.

(5) Background Traffic. Trips made by persons preparing for the arrival of a hurricane. These trips may be shopping trips to gather supplies and/or trips from work to home to assist the family in evacuation.

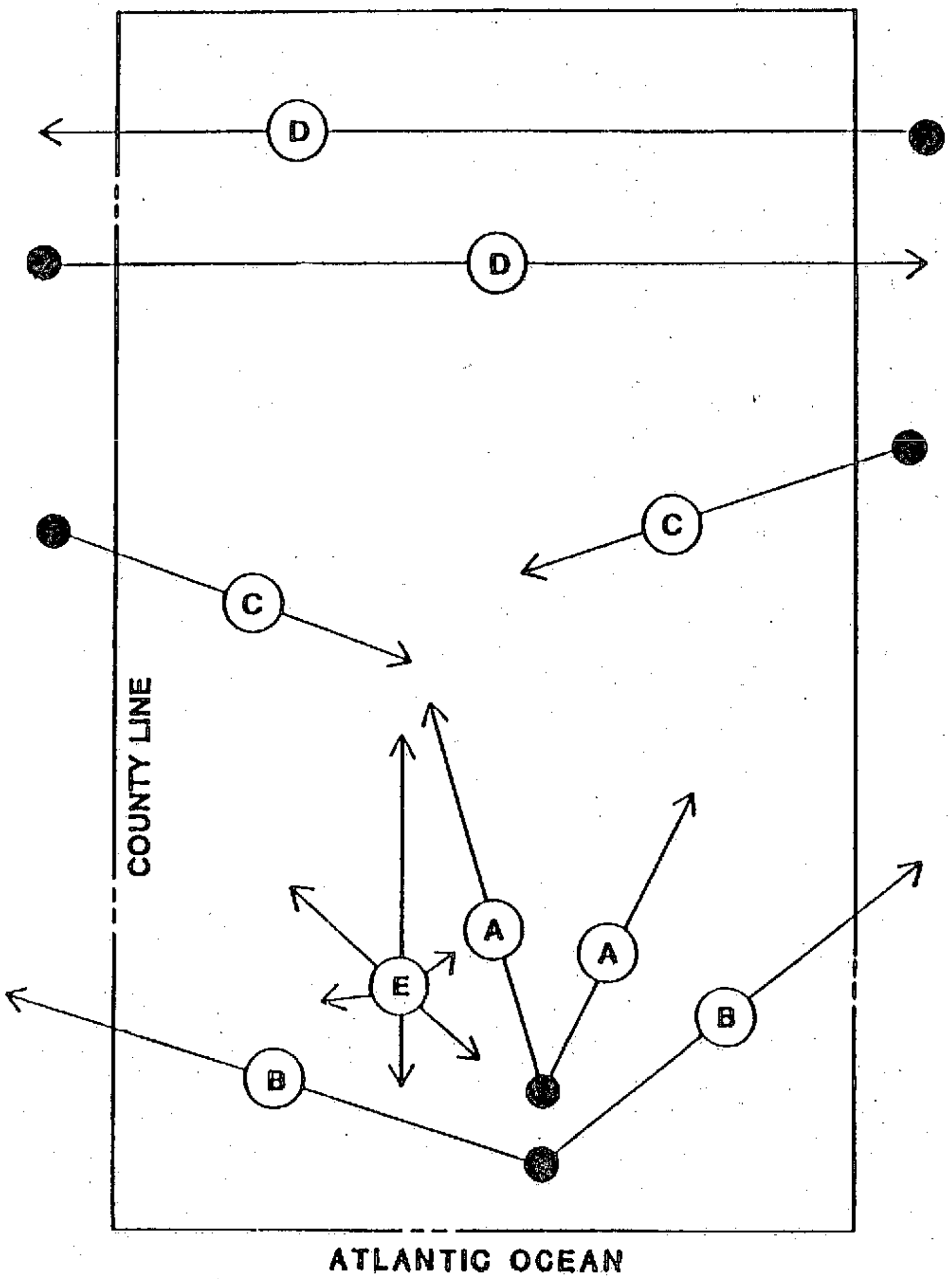
Figure 6-1 graphically depicts these traffic movement patterns associated with hurricane evacuations. It is important to recognize that three of the five defined patterns involve traffic movement generated outside of the county. It is evident that, depending upon the assumed evacuation scenario, these inter-county movements result in a number of regional traffic impacts. During the transportation analysis task, these movements were quantified to aid in estimating roadway congestion and resulting clearance times.

Transportation Analysis Input Assumptions

a. General. Since all hurricanes differ in some respects, it is necessary to set forth clear assumptions about storm characteristics and evacuee response before transportation modeling can begin. Various storm characteristics, particularly hurricane intensity, affect the perception of threat by coastal residents and cause a wide variation in evacuation response.

The transportation analysis culminates in the calculation of clearance and evacuation times, which are based on a set of assumed conditions and behavioral responses. Since the circumstances under which future hurricane evacuations are conducted may vary widely, a series of sensitivity analyses was performed during the transportation modeling. Those variables having the greatest influence on clearance times were identified and then varied to establish a logical range within which the actual input assumption values might fall. Key assumptions for the transportation analysis, which are discussed in the remainder of this chapter, are grouped into the following five areas: (1) Permanent Resident and Tourist Population Data, (2) Storm Scenarios, (3) Evacuation Zones, (4) Behavioral Characteristics of the Evacuating Population, and (5) Roadway Network and Traffic Control Assumptions.

EVACUATION TRAVEL PATTERNS



(A) In-County Origins To In-County Destinations

(B) In-County Origins To Out-Of-County Destinations

(C) Out-Of-County Origins To In-County Destinations

(D) Out-Of-County Origins To Out-Of-County Destinations

(E) Background Traffic

Figure 6–1

b. Permanent Resident and Tourist Population Data. A population data base for each county within the study area was initially developed using 1989 projections of Census data. This source of data provided a reliable base for permanent population parameters on a sub-county basis. Since data are regularly updated for each of these geographic units, their use provides a means to facilitate updating of the evacuation study in the future. A data base containing tourist-related dwelling units and population was developed through Census sources and State and local planning agencies.

Table 6-1 lists the 1989 total number of permanent, mobile home, and tourist dwelling units projected for each county within the study area. Baltimore City, Baltimore County, and Prince George's County have the largest number of permanent resident dwelling units, with Anne Arundel and St. Mary's Counties having a particularly large number of mobile homes. As expected, Worcester County has the largest estimated number of tourist units, due to the Ocean City resort area.

In addition to the number of dwelling units, data were gathered concerning the number of people and number of vehicles per dwelling unit. These data were crucial to translating hurricane vulnerable housing units to vehicle demand for roadways and demand for shelter spaces.

c. Hurricane Evacuation Zones and Scenarios. In the vulnerability analysis, those areas which were likely to experience hurricane storm surge were identified and graphically shown on the MEOW maps. This information, which became one of the key inputs to the transportation analysis, was used to determine which areas should be evacuated. In the transportation analysis, it was assumed that all persons living in areas flooded by storm surge should be evacuated. This evacuee group included permanent residents living in single-family, multifamily, or mobile home units, as well as tourists staying in hotel/motel, condominium, time share units, and campsites located in storm surge vulnerable areas. In addition, all mobile home residents living outside the hurricane flooded areas of each county were assumed to evacuate due to high wind vulnerability.

After establishing the vulnerable population for a particular storm situation, it was necessary to develop a series of zones to geographically locate and quantify the evacuees. Evacuation zones also provide a base to model traffic movements from one geographic area to another. A series of zones was established for each county based on the following factors:

(1) Zones should relate to expected surge flooding limits (based on MEOWs) for each storm scenario.
(2) Zones should relate well to Census, traffic analysis zone, or other data base units.
(3) Zones should be defined, if possible, for ease of use in issuing an evacuation order or advisory.
(4) Zonal boundaries should include identifiable natural features, roadways, or landmarks.
(5) Rural counties should have no more than 20 zones and counties with major urban areas should have no more than 35 zones. (This rule of thumb was unachievable in some areas due to geography.)
(6) Small "pocket" zones that would be isolated by surrounding surge should be avoided.
(7) Zones should be able to be served by major evacuation routes.
(8) Zones should have relatively balanced population levels.
(9) Zones must allow for appropriate transportation modeling.

TABLE 6-1

1989 ESTIMATED PERMANENT AND TOURIST/SEASONAL DWELLING UNIT DATA

COUNTY	TOTAL PERMANENT	YEAR-ROUND MOBILE HOME	TOURIST/ SEASONAL
Anne Arundel	144,765	3,254	2,605
Baltimore City	320,775	319	228
Baltimore County	251,741	1,915	293
Calvert	13,332	630	224
Caroline	9,347	817	5
Cecil	24,429	1,755	2,018
Charles	23,987	900	109
Dorchester	12,172	710	350
Harford	52,332	2,522	95
Kent	6,854	290	612
Prince Georges	250,646	550	134
Queen Anne's	12,449	521	356
St. Mary's	25,249	2,561	217
Somerset	8,575	635	257
Talbot	12,432	439	103
Wicomico	26,418	1,461	171
Worcester	23,870	1,274	12,620
TOTAL	1,219,373	20,553	20,397

Table 6-2 provides the number of evacuation zones delineated in each Eastern Shore county for the transportation analysis. Corresponding evacuation zones maps for the Eastern Shore counties are included in Appendix A. Because transportation analyses were not performed for the remaining counties, it was not necessary to sub-divide the evacuation zones. Thus, the evacuation zones for the Western Shore counties are simply the inundation zones illustrated on the inundation maps located in Appendix A. Local emergency management officials in these counties should refer to the following chart to determine which areas to evacuate during a hurricane. For any given hurricane category, all residents in the following inundation zones should evacuate.

COUNTY	STORM CAT 1	STORM CAT 2	STORM CAT 3	STORM CAT 4
Baltimore City	1	1,2	1,2,3	1-4
Baltimore County	1	1,2	1,2,3	1-4
Calvert	1	1,2	1,2,3	1-4
Cecil	1	1,2-3	1,2-3	1-4
Charles	1	1,2	1,2,3	1-4
Harford	1	1,2-3	1,2-3	1-4
Prince George's	1	1,2	1,2,3	1-4

As described in the vulnerability analysis, the hurricane evacuation scenarios for each county represent combinations of hurricane intensities having essentially the same areas and numbers of people affected by storm surge. To develop the scenarios, enumeration districts, Census tracts, and traffic analysis zones (where appropriate) were mapped and then overlaid with storm surge limits corresponding to the four hurricane categories being considered in this study. This procedure identified areas where major increases in storm surge inundation and vulnerable population occur with each progressive step in hurricane intensity.

d. Behavioral Assumptions. The data developed in the behavioral analysis were utilized to derive the best assumptions possible for the transportation analysis. Specifically, for transportation modeling purposes, the following behavioral information was utilized.

(1) Participation Rates. Evacuation participation rates are expressed by percentages of residents within each evacuation zone that can be expected to evacuate under various hurricane threats. Post-hurricane response studies indicate that considerable variation has occurred in evacuation participation from place to place in the same event, as well as from storm to storm in the same location. These participation rates were estimated in the behavioral analysis, and a summary appears in Table 1 of Appendix C, the Behavioral Analysis.

(2) Response Rates. Perhaps the most critical behavioral aspect that must be considered for the transportation analysis is the response rate of the evacuating population. Behavioral data from research of past hurricane evacuations show that mobilization and departures of the evacuating population occur over a period of many hours. For the Maryland Hurricane Evacuation Study, clearance time sensitivity was tested using mobilization rates specified by three different behavioral response curves. These response curves, describing mobilization rates of the vulnerable population, define the cumulative percentage of evacuating vehicles loading onto the evacuation roadway network in hourly intervals relative to an evacuation advisory. Thus, the percentage of evacuees leaving each

TABLE 6-2
VULNERABLE POPULATION
BY STORM SCENARIO AND COUNTY

COUNTY	1989 POPULATION ESTIMATE	STORM CATEGORY	VULNERABLE POPULATION	PEOPLE GOING TO PUBLIC SHELTER
Anne Arundel	423,475	1-2, low season	44,540	4,530
		1-2, high season	48,540	4,730
		3-4, low season	54,330	5,845
		3-4, high season	59,015	6,080
Caroline	24,545	1-4	2,860	750
Dorchester	30,070	1	6,460	630
		2-3	8,160	790
		4	12,780	1,465
Kent	16,965	1-4	3,040	550
Queen Anne's	32,565	1-2	11,470	1,395
		3-4	17,620	2,290
St. Mary's	71,075	1-4	16,215	3,465
Somerset	21,700	1	13,210	840
		2-3	14,985	990
		4	16,365	1,175
Talbot	28,580	1	9,070	1,085
		2-4	12,660	1,630
Wicomico	72,465	1	5,200	1,100
		2-3	6,670	1,250
		4	8,155	1,480
Worcester (figures include Ocean City population)	37,745 (permanent)	1-2, November	20,810	1,645
		1-2, shoulder weekend	91,600	5,180
		1-2, summer weekday	132,050	7,200
		1-2, summer weekend	212,950	11,250
		3-4, November	30,135	2,640
		3-4, shoulder weekend	117,425	7,000
		3-4, summer weekday	167,305	9,495
		3-4, summer weekend	286,815	19,420
Ocean City	250,000 (seasonal maximum)	1-2, November	13,575	685
		1-2, shoulder weekend	83,505	4,480
		1-2, summer weekday	123,465	6,175
		1-2, summer weekend	203,385	10,175
		3-4, November	18,125	1,010
		3-4, shoulder weekend	104,555	5,330
		3-4, summer weekday	153,945	7,800
		3-4, summer weekend	252,730	12,740

evacuation zone is available for the calculations related to traffic loadings at critical links along the evacuation roadway network.

The behavioral response curves shown in Figure 6-2 are intended to include the most probable range of rates at which evacuees enter the roadway network that might be experienced in future hurricane evacuation situations. The slow response curve is intended to depict the response by evacuating households to an evacuation advisory given with ample warning time. The medium and rapid response curves are more realistic. They reflect the behavior of evacuees when an evacuation warning is given with adequate, but not ample, warning time, and the perceived threat is acknowledged by the evacuees. The immediate response curve illustrates the quickest response by evacuees. This response is observed when a hurricane's conditions worsen or change course, or in reaction to a very strong evacuation advisory with limited warning time.

(3) Evacuee Destinations. The percentage of evacuees assumed to go to one of four general destination types was an important behavioral input to the transportation analysis. Evacuee destination percentages developed in the behavioral analysis were refined in coordination with the disaster preparedness committees in each county. Figures were developed for the expected percentage of evacuees going to public shelter facilities, hotel/motel units within the study area counties, the home of a friend or relative, or out of the county. Destination percentages were varied for each evacuation zone in each county based upon the relative vulnerability of the zone. This behavioral analysis is discussed in further detail in Chapter 4 and in Appendix C.

(4) Vehicle Usage Rates. The vehicle usage rates refer to the percentage of all vehicles available to evacuees that will be utilized in a hurricane evacuation, including those vehicles expected to tow a trailer, as well as recreational vehicles. A review of the behavioral data and discussions with the disaster preparedness officials provided the needed parameters. Overall, vehicle usage is estimated to be 70 percent for all counties except for Worcester and Anne Arundel Counties, where the vehicle usage rate is estimated to be 90 percent and 50 percent, respectively.

Transportation Modeling Methodology

a. General. The transportation modeling employed for the Maryland Hurricane Evacuation Study area involved a number of manual and microcomputer techniques. The methodology, while very technical, was designed to be consistent with the accuracy level of the modeling inputs and assumptions. The methodology is unique in that it is sensitive to the key behavioral response of evacuees. This methodology was applied to the Eastern Shore counties within the study area, as well as to Anne Arundel and St. Mary's Counties. Appendix D explains in detail the steps used in the transportation modeling. The modeling methodology involved seven major steps, which are described below.

b. Evacuation Zonal Data Development. Data gathered by Census tract were grouped by evacuation zone. Numbers of permanent resident dwelling units, mobile homes, and tourist units were compiled by zone and formatted for input into the trip generation analysis.

c. Evacuation Roadway Network Designation. In choosing roadways for the evacuation network, an effort was made to include only those streets and roads not subject to flooding from heavy rainfall or from potential surge heights expected prior to the arrival of sustained gale-force winds. Other desirable characteristics were little or no adjacent tree coverage, substantial shoulder width and surface, and designation as an evacuation route in an existing hurricane evacuation plan. The evacuation roadway network developed for

BEHAVIORAL CUMULATIVE EVACUATION CURVES

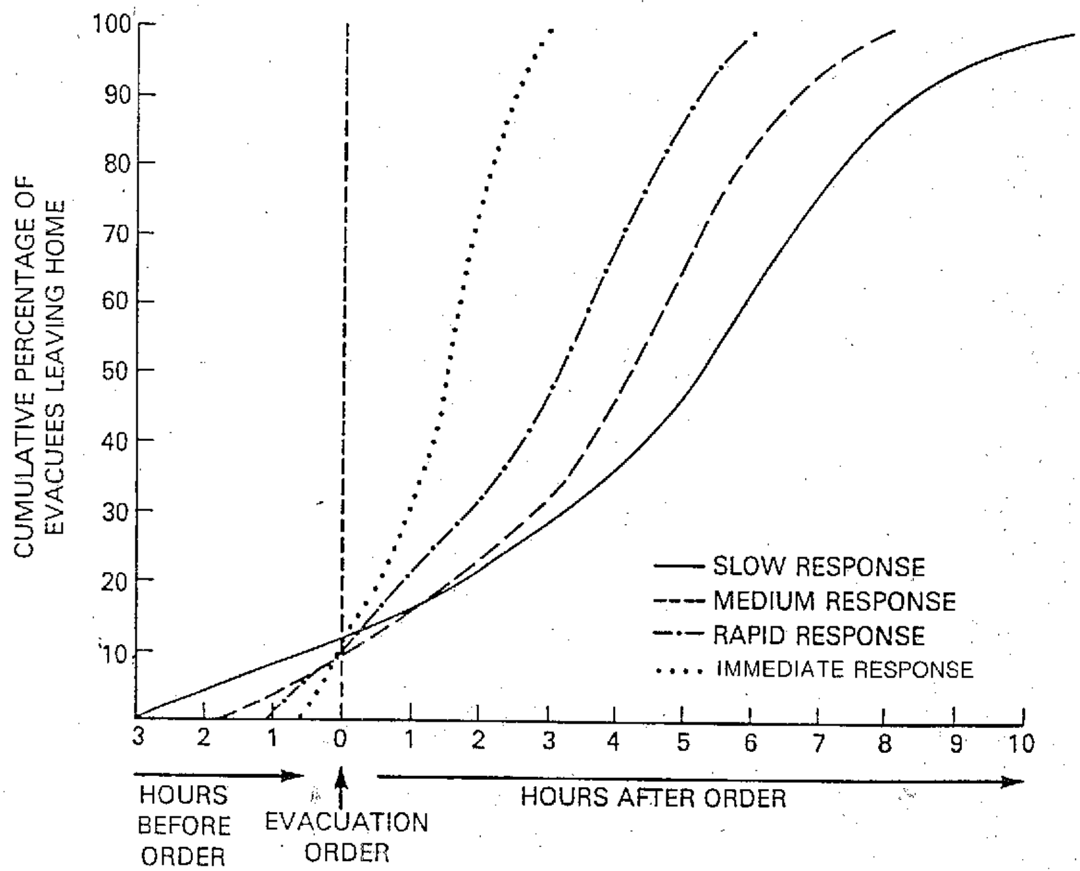


Figure 6-2

each county was presented to the emergency management officials and the appropriate traffic engineers and planners for comments or changes before the modeling began.

In order to determine the routing of evacuation traffic, a representation of the roadway system was developed. A traditional "link-node" system was developed to identify roadway sections. Nodes are used to identify the intersection of two roadways or changes in roadway characteristics. Links are the roadway segments between any two nodes.

Once the links and nodes for the evacuation routes were identified, roadway characteristics were specified for each link. The characteristics of each link were defined by the following features:

(1) Number of travel lanes

(2) Type of facility (arterial, collector, freeway, etc.)

(3) Area type (surrounding land use)

The evacuation roadway networks for Anne Arundel and St. Mary's Counties and for each Eastern Shore county are presented in Appendix A. Due to the limited inundation areas and low number of expected evacuating vehicles, evacuation roadway networks were not determined for the remaining counties.

The significance of link-node segments and centroid connectors (dashed lines) is explained in Appendix D, the Transportation Model Support Document. The figures show all the major roadways in the study area, while identifying the evacuation routes in red. Detailed roadway link information is contained in Appendix D.

In the transportation modeling, it was assumed that an evacuation would be completed prior to the arrival of sustained 34-knot (39 mph) winds (gale-force) or roadway inundation and would, therefore, be unhampered by the complications associated with gale-force winds. Clearance times were based on the assumption that all evacuees would reach their destination before the arrival of gale-force winds. Thus, it was assumed that all bridges would be safe for use throughout the entire evacuation process. Another important assumption was that all bridges would remain closed for boat traffic and available only to vehicular traffic during the evacuation period. Bridge openings obviously result in less than full hourly capacity for vehicular movement; therefore, the time required for any bridge openings planned during an actual hurricane evacuation event must be added to the clearance times calculated for each of the study area counties.

It was further assumed that law enforcement officers would be assigned to critical intersections during an evacuation. This would allow for smoother traffic flow and increased intersection "green time." The transportation modeling also assumes that provisions would be made for removal of vehicles in distress during the evacuation.

The information developed concerning the evacuation roadway network was coded into a link file for use by the trip assignment computer module. The end product of this step was a computerized representation of the roadway system.

d. <u>Trip Generation</u>. Specific dwelling unit variables were used in the trip generation calculations to produce total numbers of evacuating population and vehicles originating from each evacuation zone. Originating vehicles and population were grouped by destination type based on previously established behavioral and population parameters. Hotel/motel information, coupled with public shelter capacity information, was used to develop estimates of the number of evacuating vehicles that would find acceptable destinations in each zone.

e. Trip Distribution. This step concentrated only on those trips originating in a county and finding acceptable destinations within the same county. The numbers of vehicles evacuating from each zone were matched with available destinations in all zones. The end product of the task was a trip table showing trips between each zone and all other zones for each evacuation destination type. A unique trip table was developed for each storm scenario and for each tested behavioral response assumption.

f. Roadway Capacity Development. Number of lanes, area types, and facility-type information for each roadway link in the evacuation network were translated into a general 24-hour service volume for comparative purposes. Specific hourly flow rates were then developed for the most critical roadway segment and intersections.

g. Trip Assignment. This step included the use of a microcomputer program to assign zone to zone trips for in-county to in-county travel onto the road segments included in the previously computerized roadway system. All other categories of evacuation travel patterns (in-county to out-of-county, out-of-county to in-county, out-of-county to out-of-county, and background traffic) were then added in to arrive at total evacuation vehicles per roadway segment. A series of volume-to-capacity ratios were then developed to determine which roadway segments would be most congested by evacuation vehicles. Those links with the highest volume-to-capacity ratios were identified as critical links for each county.

h. Calculation of Clearance Times-Travel Time/Queuing Delay Analysis. This step involved a detailed look at the critical links and intersections identified for each county of the study area. Initially, evacuation zones using the critical link of interest were identified. Evacuation vehicles from each zone were then released to the network in accordance with specific behavioral response curves. Based upon an assumed hourly capacity for the critical link, the hourly volume desiring to use the link was then translated into a queuing delay time at the link and an evacuation travel time. The end product of this major step was a set of clearance times, by county, for each storm scenario.

Model Application

a. General. Application of the transportation modeling methodology produced several key data items for hurricane evacuation planning and preparedness. Completion of the transportation modeling produced the following:

(1) Evacuating population and vehicle parameters

(2) Shelter demand and capacity considerations

(3) Traffic volumes and critical roadway segments

(4) Estimated clearance times

Although many pieces of information are produced in the transportation analysis, these data items are most critical to planning shelter needs, developing traffic control measures, and defining the timing requirements of an evacuation.

b. Evacuating Population and Vehicle Parameters. Using a microcomputer process, total evacuating vehicles and population produced from each evacuation zone were split by destination type: public shelter, hotel/motel unit, home of friend/relative, or out of region. This was accomplished for each storm scenario for each county and further refined by assumed behavioral characteristics of the population at risk. Appendix D provides these data by county.

Table 6-3 provides ranges of evacuating population and vehicle statistics for each Eastern Shore county within the study area. The numbers of people evacuating and vehicles expected to be utilized in hurricane evacuations are given in ranges which reflect the effect of testing different storm scenarios and tourist unit occupancies. Thus, the highest number relates to a high seasonal occupancy and the most severe hurricane storm category. Figures are based on 1989 population estimates and a 100 percent evacuation of all vulnerable areas within the Maximum Envelope of Water inundation limits. It is important to remember that evacuating population figures include all mobile home residents, regardless of their location, and a small percentage of persons who will evacuate, although theoretically who are not vulnerable.

c. Shelter Demand/Capacity Considerations. While the data discussed above are extremely important, they are most useful when matched with available sheltering. It is important to note that evacuating population and vehicle statistics, evacuation zone data, and destination type reflect where evacuees would go, assuming sufficient safe destinations were available. The public shelter demand/capacity data produced by the shelter analysis were utilized to route evacuees to available public shelters within the study area.

Table 5-19, Chapter 5, provides the calculated public shelter demand and available capacity by storm scenario for each county. Shelter demand figures are given in a range for those counties where varied seasonal occupancy was analyzed.

d. Traffic Volumes and Critical Roadway Segments. Appendix D provides the assigned evacuating vehicle figures for all roadway segments in each county's evacuation roadway network. In addition, that document provides the volume-to-capacity ratios calculated for each link. Those roadway segments with the highest volume-to-capacity ratios were identified as the critical links for each county. Table 6-4 lists the critical roadway segments for Anne Arundel and St. Mary's Counties and for the Eastern Shore counties. Critical links and intersections are listed in order of severity. These links control the flow of evacuating traffic during a hurricane evacuation and are key areas for special traffic control.

Clearance times were based on the assumption that all evacuees would reach their destination before the arrival of gale-force winds (39 mph). Thus, it was assumed that all bridges and elevated roadways would be safe for use throughout the entire evacuation process. Bridges listed as critical links are listed due to high traffic volume, rather than because of hazardous driving conditions.

Because transportation analyses were not performed for the Western Shore counties, no evacuation zones or critical links were determined. However, evacuation areas and roadways which may present difficulties were identified for all of the counties in the study area. These include areas located on peninsulas and islands which may be easily inundated and which may have limited departure routes. Also included are points along any likely evacuation routes which may be inundated and bridges which should be crossed before gale-force winds arrive. These areas are listed at the end of this chapter in Table 6-5.

e. Calculated Clearance Times. The most important products of the transportation analysis are the county clearance times, developed by storm scenario and behavioral response. Clearance time is the time required to clear all evacuating vehicles from the

TABLE 6-3

TRANSPORTATION ANALYSIS EVACUATING PEOPLE
AND VEHICLE STATISTICS BY COUNTY

COUNTY	NUMBER OF PEOPLE EVACUATING DWELLING UNITS*	NUMBER OF VEHICLES EVACUATING DWELLING UNITS
Anne Arundel	44,540 - 59,015	17,570 - 22,450
Caroline	2,860	1,505
Dorchester	6,460 - 12,780	3,550 - 6,740
Kent	3,040	1,645
Queen Anne's	11,470 - 17,620	6,760 - 10,015
St. Mary's	16,215	5,755
Somerset	13,210 - 16,365	7,420 - 8,995
Talbot	9,070 - 12,660	5,630 - 7,615
Wicomico	5,200 - 8,155	2,450 - 3,820
Worcester (figures include Ocean City evacuees)	20,810 - 286,815	16,490 - 105,530
Ocean City	13,575 - 252,730	12,544 - 88,130

* A range of people and vehicles is given due to the effect of testing different storm scenarios and seasonal occupancies. The lower figure would represent a Storm Scenario A, low seasonal occupancy situation. The higher figure represents the worst case situation in terms of storm intensity and high seasonal occupancy.

TABLE 6-4

TRANSPORTATION ANALYSIS CRITICAL ROADWAY SEGMENTS

ANNE ARUNDEL COUNTY

U.S. 50/U.S. 301 between Bay Bridge and Governor Ritchie Highway
U.S. 50/U.S. 301 between Governor Ritchie Highway and I-97
Mayo Road and Solomons Island Road intersection
Forest Drive and Solomons island Road intersection
U.S. 50/U.S. 301 and Solomons Island Road interchange
Rowe Boulevard and U.S. 50/U.S. 301 interchange

CAROLINE COUNTY

(Route 404 and U.S. 50 intersection outside county)
Route 404 and Route 16 intersection
Route 404 and Route 480 intersection at Hillsboro

DORCHESTER COUNTY

Frederick C. Malkus Bridge
U.S. 50 and Cambridge - Hudson Road intersection at Cambridge
U.S. 50 and Church Creek Road intersection
U.S. 50 through the county

KENT COUNTY

Rock Hall Avenue northeast of Rock Hall
Eastern Neck Island Road
Broadneck Road and Langford Road intersection

QUEEN ANNE'S COUNTY

U.S. 50/Route 404 intersection
U.S. 50/U.S. 301 interchange
Lane Memorial Bridge (Bay Bridge)
Kent Point Road and U.S. 50/U.S. 301 intersection
Cox Neck Road and U.S. 50/U.S. 301 intersection
Dominion Road and U.S. 50/U.S. 301 intersection

ST. MARY'S COUNTY

Route 5 at Leonardtown
Piney Point Road and Route 5 intersection
Route 5 north of Scotland Beach
Morganza Turner Road and Route 235 intersection

TABLE 6-4 (continued)

SOMERSET COUNTY

Crisfield Westover Road and U.S. 13 intersection
Crisfield Westover Road and Route 137 intersection at Marion
Deal Island Road and U.S. 13 intersection
Crisfield Westover Road and Fairmont Road
U.S. 13 through Princess Anne

TALBOT COUNTY

Frederick C. Malkus Bridge
Route 404 and U.S. 50 intersection
U.S. 50 at Easton
Easton Claiborne Road through St. Michael's
Easton Claiborne Road and Washington Street intersection (Easton)

WICOMICO COUNTY

U.S. 50 and Old Ocean City Road intersection
Route 349 and U.S. 50 intersection
Salisbury Boulevard (Bus. 13) and U.S. 50 interchange
Salisbury Nanticoke Road and Whitehaven Road intersection

WORCESTER COUNTY and OCEAN CITY

Route 90 and U.S. 50 interchange
Route 528 (Ocean Highway) and Route 90 intersection (Ocean City)
U.S. 50 and Philadelphia Avenue intersection at Ocean City
U.S. 113 (Berlin Road) and U.S. 50 interchange
Route 346 and U.S. 50 intersection northwest of Berlin
U.S. 50 - Kelly Bridge
Route 90 - Isle of Wight Bridge

roadway network. Clearance time begins when the first evacuating vehicle enters the roadway network, as defined by a behavioral response curve, and ends when the last vehicle reaches an assumed point of safety. Clearance time includes the mobilization time required by evacuees to secure their dwellings and prepare to leave, as well as the travel time spent by evacuees traveling along the roadway network due to traffic congestion. Clearance times do not relate to the time any one vehicle spends on the roadway network.

Clearance time is a critical component of evacuation time. In order to ensure that evacuees can reach safety before the arrival of hazardous weather conditions, clearance time must be considered with respect to the arrival of sustained gale-force winds. Evacuation time is the sum of clearance time and pre-landfall hazards time, which is the time period from the arrival of sustained gale-force winds until the hurricane eye makes landfall. Thus, evacuation time for a community can be many hours longer than clearance time. Figure 6-3 illustrates the relationship of these evacuation considerations.

Table 6-6, at the end of the chapter, presents the clearance times estimated for each Eastern Shore county and for Anne Arundel and St. Mary's Counties. Clearance times are stratified by storm scenario, by rate of response on the part of the evacuating population, and by level of tourist occupancy. Where appropriate, clearance times are also stratified by traffic control strategy. Clearance times for the remaining Western Shore counties are equal to the appropriate response curve times.

The clearance times shown in Table 6-6 are some of the longest times ever calculated for eastern seaboard and gulf coast states. Two issues are responsible, to a great extent, for the length of these times; the number of tourists leaving Ocean City and the evacuees in Delaware passing through Maryland. The most critical road link in the entire Maryland network is the U.S. Route 50/Maryland Route 404 intersection located on the borders of Talbot and Queen Anne's Counties. A comparison of the transportation analyses of the Delaware Hurricane Evacuation Study and the Maryland study demonstrated that this intersection has the highest volume-to-capacity ratio in Maryland and Delaware. The effect of this traffic flow is seen in the extraordinarily long clearance times for Talbot, Queen Anne's, and Wicomico Counties.

The Delaware study indicated that approximately one-third of the evacuating traffic leaving Sussex County, Delaware or traveling north through Sussex County from the Ocean City area will be traveling west toward the Chesapeake Bay Bridge. Concern for evacuees traveling west through Delaware or Maryland prompted an investigation of a new traffic control measure. As part of the Delaware study, a transportation analysis was performed which calculated Delaware county clearance times based on the diversion of all Sussex County evacuating traffic northward through Delaware, allowing none of these vehicles to travel westward through Maryland.

By prohibiting traffic from Delaware to travel west through Maryland along Route 404 (or along any parallel route), the clearance times in the Delaware counties would increase by up to 7 hours. Clearance times in Maryland would correspondingly decrease by up to 13 hours in Talbot County. Without this traffic control measure, the clearance times of Delaware are much lower than those of Talbot, Queen Anne's, and Wicomico Counties. Imposing this traffic diversion would cause the clearance times of both states to become more equal. However, because the Maryland study cannot assume that this diversion will be implemented, the clearance times presented in this document reflect traffic from Delaware traveling westward through Maryland. Although the clearance times range from 9 to 44 hours, they do not suggest that it will take from 9 to 44 hours for local residents to reach local shelters or the homes of friends and relatives. Instead, they suggest that

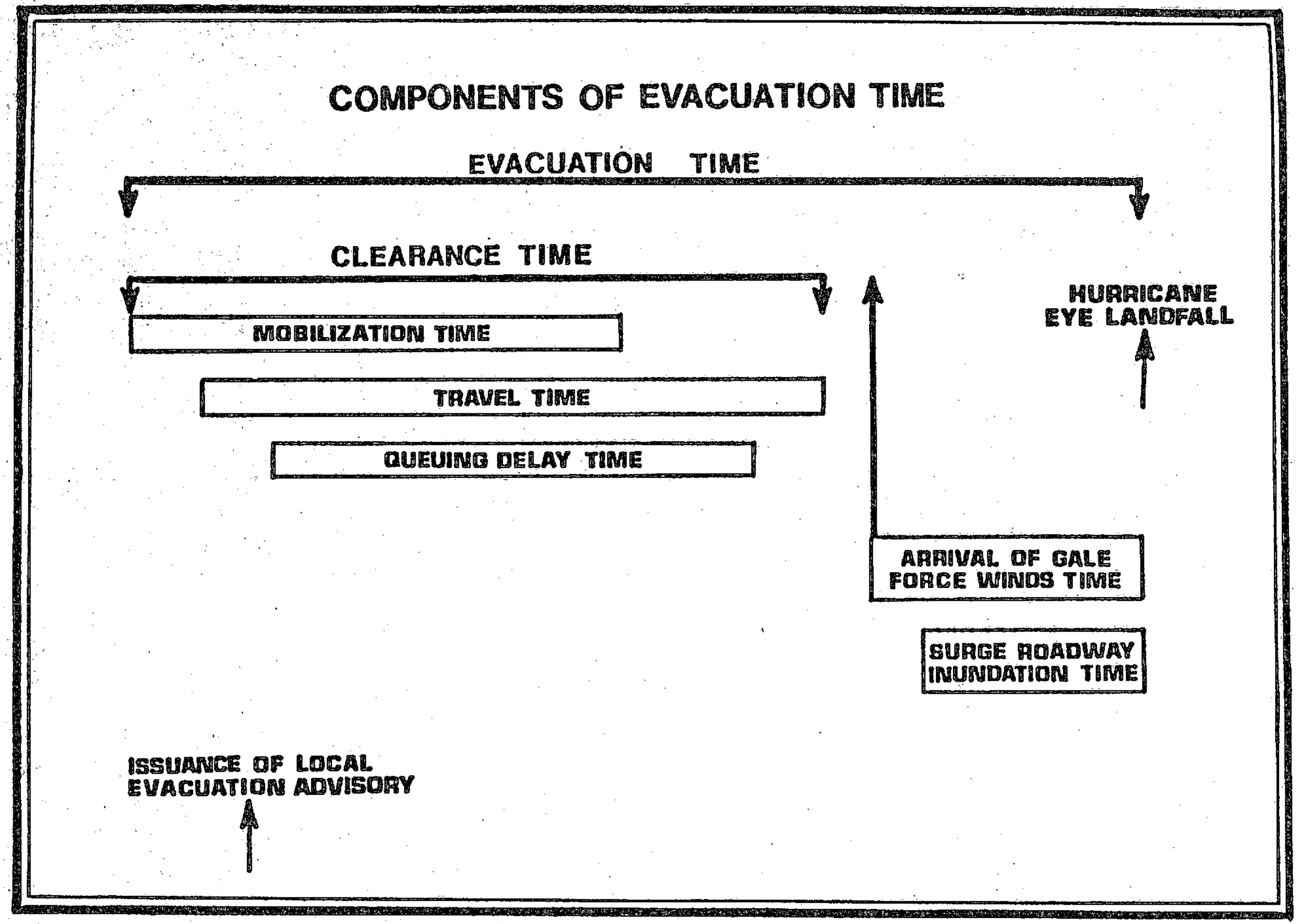

COMPONENTS OF EVACUATION TIME
EVACUATION TIME
CLEARANCE TIME
MOBILIZATION TIME
TRAVEL TIME
QUEUING DELAY TIME
HURRICANE EYE LANDFALL
ARRIVAL OF GALE FORCE WINDS TIME
SURGE ROADWAY INUNDATION TIME
ISSUANCE OF LOCAL EVACUATION ADVISORY

FIGURE 6-3

evacuating vehicles will occupy the road network for this length of time. In general, it will take local residents from 4 to 9 hours to reach their evacuation destination.

It is important that evacuation decision-makers understand that the calculated clearance times assume all roadways are continually open to vehicular traffic. Any lengths of time spent with bridges closed to vehicular traffic in order to allow for boat traffic must be added to the calculated clearance times.

Local officials should carefully coordinate evacuation plans with the Maryland Department of Natural Resources Boating Administration and other agencies responsible for controlling boat traffic on the waterways to allow for a safe and orderly evacuation. Specifically, boaters should be told to take the following actions:

- Monitor the National Weather Service Marine Weather Broadcasts for their areas.

- Complete boat protection preparations 48 hours before the expected arrival of the hurricane.

- Move trailerable boats and trailers to high ground rather than pulling them behind a car during the general evacuation.

- Do not stay on a boat, and evacuate when told to do so.

f. Traffic Control Measures. The movement of evacuating vehicles during a hurricane evacuation requires extensive traffic control efforts to achieve maximum use of roadway capacity and to expedite safe escape from hurricane hazards. The development of traffic control techniques for critical evacuation routes should always involve the U.S. Coast Guard, local police, State highway patrolmen, and fire and emergency management personnel. The following traffic control techniques/strategies were discussed with disaster preparedness officials.

(1) As available manpower allows, two officers should be stationed at each critical intersection, one to move traffic, the other to assist disabled vehicles. Critical links and intersections discussed previously should be used as a starting point in developing manpower assignments.

(2) All available tow trucks should be positioned along key travel corridors and, especially, critical links. At a minimum, tow trucks should be at major bridge crossings to remove disabled vehicles.

(3) Where intersections will continue to have signalized control, signal patterns providing the most "green time" for the approach leading away from the coast should be actuated by the State Department of Transportation field office.

(4) All draw/swing bridges needed for evacuation should be locked in the "down" position during a hurricane warning. Boat owners must be made aware of flotilla plans and time requirements for securing vessels. All preparations for boat security should be completed at least 48 hours before the hurricane arrival to allow for home preparation and family evacuation. Optimally, industrial and recreational vessels should be moved to safe harbor during or before a hurricane watch.

(5) In densely populated coastal areas where expected traffic volumes greatly exceed available roadway capacity, reversal of normal flow on inbound lanes has been used on

roadway facilities having three or more lanes; however, one lane moving against the flow of evacuation traffic must always be kept open for emergency vehicles and transit vehicles picking up stranded or pedestrian evacuees.

(6) Manual direction of traffic should be supplemented by physical barriers/cones that are adequately weighted down and placed to channel traffic and prevent unnecessary turning and merging conflicts. This strategy can be used effectively at interchanges listed previously in the critical link/intersection tables.

(7) The movement of mobile homes and campers along evacuation routes should be minimized after a hurricane warning is issued. A disabled mobile home could block the only escape route available for evacuation in some areas. Such vehicles are difficult to handle late in an evacuation due to sporadic wind gusts.

(8) Once an evacuation begins, provisions should be made for suspension of tolls in order to maintain traffic flow on facilities such as the Bay Bridge in Maryland. Although the Bay Bridge toll only applies to eastbound traffic, which should be discouraged during a hurricane evacuation, consideration should be given to the suspension of this toll during recovery operations when evacuees are returning to their homes and emergency vehicles and cleanup crews are traveling eastbound.

(9) Maryland and Delaware emergency management officials should coordinate their evacuation plans. Consideration should be given to the development of a plan to divert westbound Delaware traffic northward through Delaware and away from the Route 50/Route 404 intersection in Maryland. Such a measure would increase overall clearance times in Delaware, while decreasing them in Maryland. Individual evacuees encouraged to travel northward, rather than westward across the Chesapeake Bay Bridge, may actually reach their final destinations faster by avoiding inevitable delays along the approach to the bridge.

Whether or not the northward diversion is implemented, clearance times in Maryland will be excessively high in some counties. Under certain circumstances, Maryland and Delaware may not have access to forecasts early enough to complete evacuations before the arrival of gale-force winds or surge inundations. Maryland and Delaware officials should coordinate an advisory program to provide information to the public concerning the dangers associated with the lengthy delays on the Bay Bridge approach roadways. Individuals crossing from the Western Shore to the Eastern Shore via the Bay Bridge should be notified of the potential evacuation and associated delays. This information may encourage travelers to return to the Western Shore before an evacuation advisory is given or by a northward route, thus reducing the volume of evacuating traffic during an evacuation.

TABLE 6-5
SENSITIVE EVACUATION AREAS

ANNE ARUNDEL COUNTY

Sensitive Areas

Annapolis City Dock/U.S. Naval Academy Area
Arundel on the Bay
Avalon Shores/Shady Side/Westelee Area
Bare Neck Shore Area
Bay Ridge/Highland Beach/Tolly Point Area
Beverly Beach/Cloverlea Area
Broadwater/Deale Beach Area
Cape Anne/Franklin Manor Area
Cedarhurst on the Bay/Snug Harbor
Eastport Terrace Area
Fairhaven-on-the-Bay
Galesville Area
Gibson Island
Hackett Point/Sandy Point Area
Hog Neck Coastal Area
Hunters Harbor/Long Point Area
Idlewilde
Masons Beach/Owings Beach Area
Mimosa Cove/Rest Haven Area
Oakwood/Watergate Area
Riviera Beach
Shoreham Beach Area
Spit Neck
Turkey Point
U.S. Naval Ship Research & Devel. Ctr/Carr Pt/Greenbury Pt Area

BALTIMORE CITY

Sensitive Areas

Fairfield Area
Fells Point/Little Italy Area
Inner Harbor/Charles Center Area

TABLE 6-5 (Continued)
SENSITIVE EVACUATION AREAS

BALTIMORE COUNTY

Sensitive Areas

Breezy Point Beach Area
Harewood Area
Long Point Area
Miami Beach/Long Beach Estates/Seneca Park Beach Area
North Point
Oliver Beach Area
Sollers Point
Swan Point

CALVERT COUNTY

Sensitive Areas

Breezy Point Beach/Plum Point Area
Broomes Island Area
Burch/Buzzard Island Area
Chesapeake Beach/North Beach
Cove Point
Dares Beach
Gods Grace Point/Ramsey Creek Area
Jack Bay/Prison Point Area
Potts Point Area
Solomons Island

Sensitive Evacuation Route Points

Route 2 through Solomons Island
Route 2/4 at Johns Creek
Route 2/4 at Quakers Swamp at St. Leonard Creek
Route 2/4 at Hunting Creek/Sewell Branch
Route 4 at Hall Creek
Route 263 at Route 2/4
Route 263 at Plum Point Creek
Route 521 at Little Lyons Creek
Route 760 at Mill Creek
Route 264 through Broomes Island
Route 231 at Patuxent River Bridge

CAROLINE COUNTY

Sensitive Areas

No major sensitive evacuation areas exist in Caroline County.

TABLE 6-5 (Continued)
SENSITIVE EVACUATION AREAS

CHARLES COUNTY

Sensitive Areas

Benedict Area
Cedar Point Neck
Cobb Island
Cobb Neck
Stump Neck
Swan Point Neck

Sensitive Evacuation Route Points

Route 231 at Patuxent River Bridge
Route 254 through Cobb Island and Cobb Neck
Route 257 through Cobb Neck
Route 234 at Allens Fresh Run
Route 234 at Newport Run
Route 6 at Gumtree Cove Creek
Route 6 at Ward Run
Route 6 at Nanjemoy Creek
Route 224 at Thorne Gut Creek
Route 224 at Mattawoman Creek

CECIL COUNTY

Sensitive Areas

Carpenter Point
Charlestown
Elkton Landing/White Hall Area
North East
Pond Neck

Sensitive Evacuation Route Points

Route 213 at Bohemia River Bridge
Route 213 at Chesapeake and Delaware Canal
Route 213 at Perch Creek
Route 272 through North East
Route 7 through North East
Route 40 at Big Elk Creek
Route 40 at Little Elk Creek

TABLE 6-5 (Continued)
SENSITIVE EVACUATION AREAS

DORCHESTER COUNTY

Sensitive Areas

Asquith Island
Cambridge (downtown area)
Casson Neck
Castle Haven
Cook Point Peninsula
Elliot Island
Hills Point Neck
Hog Island
McKeil Point Peninsula
Middle Hooper Island
Parks Neck
Punch Island Road (Taylors Island)
Upper Hooper Island
U.S. Naval Reser./Bloodsworth Island (boat evacuation required)
Wroten Island (boat evacuation may be necessary)

HARFORD COUNTY

Sensitive Areas

All coastal areas of Aberdeen Proving Ground Military Reservation
Havre De Grace
Oak Landing/Mc Comas Area
Perryman
Rumsey Island/Joppatowne Area

Sensitive Evacuation Route Points

Route 40 at Church Creek
Route 7 at James Run

KENT COUNTY

Sensitive Areas

Eastern Neck Coastal Areas
Johnsontown Road Area near Deep Point
Langford Estates
Piney Neck Coastal Areas
Quaker Neck Coastal Areas
Rock Hall
Skinners Neck
Swan Point Peninsula

TABLE 6-5 (Continued)
SENSITIVE EVACUATION AREAS

PRINCE GEORGE'S COUNTY

Sensitive Areas

Eagle Harbor/Cedar Haven Area
Edmonston/North Brentwood Area
Tantallon Area

Sensitive Evacuation Route Points

Route 1 through North Brentwood
Route 301 at the Western Branch of the Patuxent River
Route 382 at Spice Creek

QUEEN ANNE'S COUNTY

Sensitive Areas

Bennett Point Peninsula
Kent Island
Mallard Point
Wye Island

ST. MARY'S COUNTY

Sensitive Areas

Cedar Landing/Tarkill Cove Area
Coltons Point/Waterloo Shores
Cornfield Harbor/Point Lookout State Park Area
Mill Point Shores
Newton Neck
Piney Point/Tall Timbers Area
St. George Island
St. Ingoes Neck
St. Jerome Beach/St. Jerome Shores
Whites Neck Coastal Areas

TABLE 6-5 (Continued)
SENSITIVE EVACUATION AREAS

SOMERSET COUNTY

<u>Sensitive Areas</u>
Champ/Oriole Area
Crisfield Area
Deal Island
Fairmount Area
Inverness
Marion Area
Mine Island
Mongrel Neck
Rumbley
Smith Island (boat evacuation required)
Victor Neck

TALBOT COUNTY

<u>Sensitive Areas</u>
Anchorage/Ingleton Peninsula
Avonvue/Bellevue
Baileys Neck Road (in Baileys Neck)
Barrett Cove Areas
Beverly Farm Area
Bolingbroke Manor/Highlys Beach
Broad Creek Road (Rt. 579) Peninsula
Bruffs Island Road/Shaw Bay/Woodland Creek Peninsula Area
Chancellor Point Peninsula
Crosiadore Creek/Holmes Creek Peninsula
Deep Neck
Dixon Creek/Tred Avon River Area
Edge View/Royal Acres/Royal Oak Area
Fairview Point Peninsula
Ferry Neck
Island Acres/World Farm Road Area
Island Neck Coastal Areas
Maxmore Creek/Travelers Rest Road Area
Miles River Neck from Gregory/Merengo Road Intersection to River. Newcomb
Oxford
Peach Orchard
Peachblossom Creek Area
Pecks Point Peninsula/Plaindealing Creek Area
Quail Hollow/Swan Villas Area
Rich Neck
St. Michaels
Solitude
Tilghman Island
Tilghman Island Road (Rt. 33) Peninsula
Trappe Landing
Tricfield
Waverly Island Estates/Waverly Road Area

TABLE 6-5 (Continued)
SENSITIVE EVACUATION AREAS

WICOMICO COUNTY

Sensitive Areas

Bivalve
Capitola/Martins Corner
Clara/New Road Landing
Cox's Corner
Deep Branch
Green Hill
Head of the Creek
Jesterville
Nanticoke
Nutters Neck
Trinity
Tyaskin
Waterview
Wetipquin Neck/Royal Oak
Whitehaven

WORCESTER COUNTY *

Sensitive Areas

Assateague Island
Bay View Estates/Cape Pleasant/Hidden Harbor Area
Cropper Island Area
Cropper Neck
Golden Quarter Neck
Isle of Wight/Martin Neck
Jenkins Neck
Lower Sinepuxent Neck
Newport Neck
Ocean City
Public Landing
St. Lawrence Neck
Scotts Landing
Turville Neck
Upper Sinepuxent Neck
Wallops Neck

* Note: Because the entire island of Ocean City is considered to be a sensitive evacuation area, it is listed under Worcester County, despite the fact that it is served by an independent Emergency Management Agency.

TABLE 6-6

CLEARANCE TIMES
BY STORM SCENARIO AND COUNTY

ANNE ARUNDEL COUNTY

	Low Seasonal Occupancy	High Seasonal Occupancy
CATEGORY 1-2 HURRICANE		
Rapid Response	9.00 (9.25)	10.00 (17.75)
Medium Response	11.75 (11.00)	13.00 (19.75)
Slow Response	15.75 (14.00)	17.50 (22.50)
CATEGORY 3-4 HURRICANE		
Rapid Response	10.25 (10.25)	11.50 (20.50)
Medium Response	13.00 (12.00)	14.50 (22.25)
Slow Response	17.25 (15.00)	19.00 (25.25)

Unbracketed numbers are the times for local in-county movements on local roads. Numbers in brackets are for roadways which are traveled by both local and Eastern Shore evacuation traffic.

CAROLINE COUNTY

	Low Seasonal Occupancy	High Seasonal Occupancy
CATEGORY 1-4 HURRICANE		
Rapid Response	12.50	18.00
Medium Response	13.50	19.00
Slow Response	15.00	20.25

Clearance times for Caroline County evacuees going to in-county destinations (and not using Route 404) will be 4 to 9 hours depending upon response to evacuation advisories.

TABLE 6-6 (continued)
CLEARANCE TIMES
BY STORM SCENARIO AND COUNTY

DORCHESTER COUNTY

	Low Occupancy (Worcester)	Medium Occupancy (Worcester)	High Occupancy (Worcester)	Worst Case Occupancy (Worcester)
CATEGORY 1 HURRICANE				
Rapid Response	5.50	11.75	16.25	20.50
Medium Response	6.25	12.25	16.50	20.75
Slow Response	9.00	13.00	17.25	21.50
CATEGORY 2-4 HURRICANE				
Rapid Response	7.50	15.50	20.75	24.00
Medium Response	8.00	15.75	21.25	24.25
Slow Response	9.25	16.50	21.75	24.75

	KENT COUNTY	ST. MARY'S COUNTY
CATEGORY 1-4 HURRICANE		
Rapid Response	4.25	4.25
Medium Response	6.25	6.25
Slow Response	9.25	9.25

Kent and St. Mary's Counties appear together for ease of presentation.

QUEEN ANNE'S COUNTY

	Low Occupancy (Worcester)	Medium Occupancy (Worcester)	High Occupancy (Worcester)	Worst Case Occupancy (Worcester)
CATEGORY 1-2 HURRICANE				
Rapid Response	11.50	19.00	26.50	31.25
Medium Response	12.25	19.75	27.00	32.00
Slow Response	13.00	20.50	28.00	32.75
CATEGORY 3-4 HURRICANE				
Rapid Response	15.00	24.25	32.75	36.25
Medium Response	15.50	24.75	33.25	36.75
Slow Response	16.50	25.50	34.00	37.50

Clearance times for Queen Anne's County evacuees going to in-county destinations (and not using westbound U.S. 50) will be 4 to 9 hours depending upon response to evacuation advisories. Lengthy clearance times reflect severe effects of Ocean City, Delaware, and Virginia traffic on road network.

TABLE 6-6 (continued)
CLEARANCE TIMES
BY STORM SCENARIO AND COUNTY

SOMERSET COUNTY

	Off Season (Virginia)	Peak Season (Virginia)
CATEGORY 1 HURRICANE		
Rapid Response	6.50	10.75
Medium Response	7.25	11.75
Slow Response	9.00	13.00
CATEGORY 2-3 HURRICANE		
Rapid Response	11.00	13.25
Medium Response	11.50	13.75
Slow Response	12.50	14.75
CATEGORY 4 HURRICANE		
Rapid Response	11.50	13.75
Medium Response	12.00	14.25
Slow Response	13.00	15.00

TALBOT COUNTY

	Low Occupancy (Worcester)	Medium Occupancy (Worcester)	High Occupancy (Worcester)	Worst Case Occupancy (Worcester)
CATEGORY 1 HURRICANE				
Rapid Response	9.75	21.25	28.75	36.00
Medium Response	10.25	21.75	29.50	36.75
Slow Response	11.50	22.75	30.50	37.50
CATEGORY 2-4 HURRICANE				
Rapid Response	14.25	28.25	37.50	42.75
Medium Response	15.00	28.75	38.25	43.50
Slow Response	16.00	29.75	39.00	44.50

Clearance times for Talbot County residents going to in-county destinations (and not using westbound U.S. 50) will be 4 to 9 hours depending upon response to evacuation advisories. Lengthy clearance times reflect severe effects of Ocean City, Delaware, and Virginia traffic on road network.

TABLE 6-6 (continued)
CLEARANCE TIMES
BY STORM SCENARIO AND COUNTY

WICOMICO COUNTY

	Low Occupancy (Worcester)	Medium Occupancy (Worcester)	High Occupancy (Worcester)	Worst Case Occupancy (Worcester)
CATEGORY 1 HURRICANE				
Rapid Response	8.25	17.50	24.00	30.00
Medium Response	9.50	18.75	25.00	31.00
Slow Response	11.25	20.50	27.00	33.00
CATEGORY 2-4 HURRICANE				
Rapid Response	10.75	22.25	30.00	34.25
Medium Response	12.00	23.50	31.25	35.50
Slow Response	13.75	25.25	33.00	37.25

Clearance times for Wicomico County residents going to in-county destination (and not using westbound U.S. 50) will be 4 to 9 hours depending upon response to evacuation advisories.

WORCESTER COUNTY *

	Low Occupancy	Medium Occupancy	High Occupancy	Worst Case Occupancy
CATEGORY 1-2 HURRICANE				
Rapid Response	4.00	8.00	11.00	14.00
Medium Response	6.00	8.75	11.50	14.50
Slow Response	9.00	9.75	12.50	15.00
CATEGORY 3-4 HURRICANE				
Rapid Response	4.00	10.25	14.00	22.00
Medium Response	6.00	10.75	14.50	22.25
Slow Response	9.00	11.75	15.00	22.50

Low Occupancy occurs in November. Medium Occupancy refers to a shoulder month weekend. High Occupancy corresponds to a summer weekday. And Worst Case Occupancy refers to a summer weekend.

* The Worcester County clearance times also apply to Ocean City.

CHAPTER SEVEN

DECISION ARCS

Purpose

The purpose of this chapter is to present the Decision Arc concept as a hurricane evacuation planning and decision-making tool and to explain the basic method of its application.

Background

Along the Atlantic seaboard, hurricanes do not ordinarily approach landfall from a direction perpendicular to the coastline but are often recurving from the tropics and make landfall on a track more nearly parallel to shore. At a typical angle of approach to the shoreline, an error of 10 degrees in predicting the hurricane track can easily mean a 100-mile difference in the point of landfall 24 hours later. Also, as hurricanes move out of the tropics toward the central Atlantic coast, they often lose their steering air currents and begin to behave somewhat erratically. In some cases, hurricanes have become totally unpredictable. Understandably, hurricane forecasting along the Atlantic coast has its uncertainties. During the 1970-79 time period, the average error of forecast landfall positions of Atlantic coast tropical cyclones (including storms of less than hurricane intensity) was about 110 nautical miles (96 statute miles) for 24-hour forecasts and about 50 nautical miles (44 statute miles) for 12-hour forecasts.

When a hurricane approaches a coastline at an acute angle, as is the usual case along the Atlantic seaboard, an error in forecast landfall position will increase or decrease the distance to landfall, possibly resulting in a significant error in the landfall forecast time. The forward motion of hurricanes can also accelerate and decelerate, causing the time of landfall to be even more unpredictable.

Since hurricane evacuation decision-making and mobilization have typically been dependent upon forecast time and position of landfall, a method is needed that will help correct for forecast errors by correlating evacuation operations in each county with hurricane position. The Maryland clearance times are so great that they may force emergency management officials to make decisions before the National Hurricane Center can provide them with meaningful information. For example, in order to successfully complete an evacuation of the Eastern Shore, an evacuation order must be given 45 hours prior to landfall. However, as Table 7-11 indicates, the maximum probability that can be associated with a hurricane's landfall position 48 hours before landfall is 13 percent. Thus, an emergency official may have to make an evacuation decision based on a relatively unlikely forecast event. The Decision Arc Method presented in this chapter is intended to guide the emergency management official through the decision-making process.

Decision Arc Components

a. General. The Decision Arc Method employs two separate but related components which, when used together, present a graphic depiction of the hurricane situation as it relates to each county. A specialized hurricane tracking chart, the Decision Arc Map, is teamed with a transparent two-dimensional hurricane model, the STORM, to describe the approaching hurricane and its relation to the area considering evacuation.

b. Decision Arc Map. In order to properly evaluate the last reported position and forecast track of an approaching hurricane, special hurricane tracking charts have been developed for each county in the study area. Superimposed on an ordinary tracking chart is a series of concentric arcs centered on the southernmost boundary of each county and spaced at 20-nautical-mile (23 statute mile) intervals. These arcs are labeled in nautical miles measured from their center and also, for convenience, alphabetically. Figures 7-1 through 7-17, which appear at the end of the chapter, show the Decision Arc Maps for each county in the study area. Figure 7-18, which is the STORM and is explained below, has a nautical mile/statute mile conversion scale to aid in the use of the Decision Arc Maps.

c. STORM. The Special Tool for Omnidirectional Radial Measurements (STORM) is used as a two-dimensional depiction of an approaching hurricane. It is a transparent disk with concentric circles spaced at 20-nautical mile intervals, their center representing the hurricane eye. These circles form a scale used to note the radii of 34-knot (39 mph) winds reported by the National Hurricane Center in the marine advisory. Figure 7-18, which follows Figures 7-1 through 7-17 at the end of the chapter, is a transparent cut-out of the STORM at scale 1 inch equals approximately 115 nautical miles (132 statute miles). The STORM has been scaled to be used in conjunction with the Decision Arc Maps and cannot be used with any other map having a different scale.

Decision Arc Method

a. General. A hurricane evacuation should be completed prior to the arrival of sustained 34-knot winds or the onset of storm surge inundation, whichever occurs first. In the Maryland Hurricane Evacuation Study area, the limiting factor for hurricane evacuation is the arrival of sustained 34-knot winds.

One of the critical components of evacuation time is clearance time, which is the time required to clear the roadways of all evacuating vehicles. Therefore, it determines the time period, in hours prior to the arrival of sustained 34-knot winds, necessary for a safe evacuation. Clearance times are based primarily on three variables: (1) the Saffir/Simpson hurricane category, (2) the expected evacuee response rate, and (3) the tourist occupancy situation.

Decision Arcs are simply clearance times converted to distance by accounting for the forward speed of the hurricane. To translate a clearance time into nautical miles (a Decision Arc distance) for use with the Decision Arc Map, a simple calculation of multiplying the clearance time by the forward speed of the hurricane in knots is necessary. This calculation yields the distance in nautical miles that the 34-knot windfield will move while the evacuation is underway. For convenience, a Decision Arc table has been developed for each Eastern Shore county that converts an array of clearance times and forward speeds to respective Decision Arcs. Tables 7-1 through 7-10 present the Decision Arcs for each Eastern Shore county and appear before the Decision Arcs at the end of the chapter.

b. Should Evacuation Be Recommended. Probability values shown in the National Hurricane Center's Public Advisory describe, in percentages, the chance that the center of a storm will pass within 65 miles of the listed locations. To check the relative probability for a particular area, the total probability for the closest location, shown on the right side of the marine advisory probabilities table, should be compared to other locations. A comparison should also be made with the possible maximums shown in the table of maximum probability values, Table 7-11. These comparisons will indicate the relative vulnerability of a particular location as compared with adjacent locations and with the maximum possible probability.

TABLE 7-11

MAXIMUM PROBABILITY VALUES

FORECAST PERIOD (hrs):	72	60	48	36	30	24	18	12
MAXIMUM PROBABILITY (%):	10	11	13	20	27	35	45	60

* Note: Probabilities listed are the maximum values assigned to any location in advance of predicted landfall. For example, the highest probability that the National Hurricane Center would assign to the event that a hurricane would strike Ocean City within 72 hours would be 10 percent. Similarly, the highest probability assigned to the event that landfall would occur within 18 hours would be 45 percent.

c. When Evacuation Should Begin. The Decision Arc Method requires that, as a hurricane approaches a particular county, an evacuation decision must be made prior to the point at which the radius of sustained 34-knot winds touches the appropriate Decision Arc (the Decision Point). For example, Figure 7-1 illustrates that, for a clearance time of 10 hours and a hurricane forward speed of 20 knots (23 mph), the evacuation should be initiated before the sustained 34-knot winds approach within 200 nautical miles (230 statute miles), the Decision Point (arc "J"). Once the sustained 34-knot winds move across the Decision Arc, there is no longer sufficient time to safely evacuate the affected population without employing extraordinary measures to hasten their departure.

In the event that the target nautical value should fall between two concentric circles, the evacuation decision should be made before the hurricane reaches the location which is farther from shore. For example, with a clearance time of 10 hours and a hurricane forward speed of 25 knots (29 mph), the evacuation should be initiated before the sustained gale-force winds approach within 250 nautical miles (288 statute miles). The decision to evacuate should be made before the gale force winds reach arc "M" at 260 nautical miles (299 statute miles) from shore. If the decision were left until the storm approached arc "L" at 240 nautical miles (276 statute miles) from shore, there would be too little time for a safe evacuation.

d. Hurricane Evacuation Decision Worksheet. The Hurricane Evacuation Decision Worksheet is designed to guide the decision-maker through the Decision Arc Method. All notes and cautions shown on the worksheet should be heeded as appropriate.

HURRICANE EVACUATION DECISION WORKSHEET

The following instructions have been developed to provide guidance in determining **if and when** an evacuation should be made for a given location. There are five basic "tools" you will need in your evacuation decision procedure: (1) County Decision Arc Map, (2) County Decision Arc Tables, (3) transparent STORM disk, (4) the National Weather Service (NWS) marine advisory, and (5) the National Weather Service (NWS) public advisory. Samples of the marine and public advisories follow the instructions listed below.

INSTRUCTIONS

1. From the NWS marine advisory, plot the last reported position of the hurricane eye on the County Decision Arc Map. Note the position with date/time. ZULU time (Greenwich mean time) used in the advisory should be converted to eastern daylight time by

subtracting four (4) hours. Plot and note the four forecast positions of the hurricane from the advisory. Table 7-12 provides the necessary time-scale conversions.

2. From the marine advisory, note the maximum radius of 34-knot winds, the forecast maximum observed or forecast sustained wind speed at landfall (to determine hurricane category), and the current forward speed. Plot the maximum radius of 34-knot winds onto the STORM disk.

3. Determine the forecast forward speed of the hurricane in knots by dividing the forward speed value in miles per hour (mph) by 1.15. Table 7-13 shows the knots/mph equivalents for wind speeds in the Saffir/Simpson hurricane scale ranges 1 through 5, and a nautical mile/statute mile conversion scale is shown on the STORM sheet located at the end of this chapter.

The forecast speed can be determined by measuring the distance in nautical miles between the first and second forecast positions (second and third plotted points) and dividing the distance by 12 (forecast positions are provided for 12 hour intervals). Compare the forecast forward speed to the current forward speed noted previously. A forecast speed greater than the current forward speed will indicate that the hurricane is forecast to accelerate, reducing the time available to the decision-maker. For counties with high clearance times (24 hours or more), the acceleration or deceleration of the storm's forward motion should be accounted for. This can be done be using the forecast position nearest your locality in place of the second forecast position in the procedure described above. Rather than dividing the distance by 12, it must be divided by the number of hours between the two forecast positions, e.g. 24 or 36.

4. Using the maximum sustained wind speed previously noted, refer to the Saffir/Simpson Hurricane Scale Table (Table 7-13) and determine the category of the approaching hurricane. With the appropriate category and the greater of the current or forecast forward speed, refer to the County Decision Arc Table and select the appropriate clearance time and corresponding Decision Arc. Mark this arc on the County Decision Arc Map.

5. Using the center of the STORM as the hurricane eye, place the STORM on the Decision Arc Map at the last reported hurricane position. Determine if the radius of 34-knot winds falls within the Decision Arc determined in Step 4 above. If so, the hurricane has passed the Decision Point (the point at which the radius of 34-knot winds crosses into the selected Decision Arc). In this case, traffic control measures and public advisories should be implemented to ensure a rapid public response in order for the evacuation to be completed prior to the arrival of sustained 34-knot winds (or consider advising no evacuation).

6. Move the STORM to the first forecast position. Again, note if the radius of 34-knot winds falls within the Decision Arc. If so, the recommendation to evacuate should be given before the hurricane eye reaches the first forecast position.

7. Estimate how many hours remain before a decision must be made by dividing the number of nautical miles between the radius of 34-knot winds and the Decision Point by the forward speed used for the Decision Arc Table. Determine if sufficient time remains to evacuate after the next NWS marine advisory will be received.

8. Compare probabilities shown in the public advisory to determine where an evacuation is likely to take place. Determine how other counties would be affected by an evacuation of your county, and when they should be notified. Check inundation maps to determine

where flooding may occur and evacuation zone maps for zones that should prepare to evacuate.

9. At the Decision Point, check the public advisory probability table for your location (see note c below). Because every hurricane situation is unique, there is no pre-determined threshold upon which evacuation orders can be given. At this point, you are encouraged to contact the Maryland Emergency Management Agency Emergency Operations Center and the National Weather Service for recommendations.

10. Steps 1 through 9 should be repeated after each NWS advisory until a decision is made by the county.

NOTES:

a. There is no built-in provision in the Decision Arc Method to allow time for evacuation of decision-making or mobilizing support personnel. These activities should be completed prior to the Decision Point. As new information becomes available in the series of marine advisories, evacuation operations should progress so that, if evacuation becomes necessary, the recommendation to evacuate can be given at the Decision Point.

b. Because information given in the marine advisory is in nautical miles and knots, the Decision Arc Maps and STORM have nautical mile scales. When utilizing hurricane information from sources other than the marine advisory, care should be taken to ensure that distances are given in, or converted to, nautical miles and speeds in knots. Statute miles can be converted to nautical miles by dividing the statute miles value by 1.15. Similarly, miles per hour can be converted to knots by dividing the miles per hour value by 1.15.

c. Probability values shown in the public advisory describe, in percentages, the chance that the center of a storm will pass within 65 miles of the listed locations. To check the relative probability for your particular area, the total probability value for the closest location, shown on the right side of the probability table in the public advisory, should be compared to other locations. A comparison should also be made with the possible maximums for the applicable forecast period shown in the table of maximum probability values listed in Table 7-11. These comparisons will show the relative vulnerability of your location to adjacent locations and to the maximum possible probability.

SAMPLE*
MARINE ADVISORY

MIATCMAT1
TTAA00 KNHC 200922
HURRICANE HUGO MARINE ADVISORY NUMBER 38
NATIONAL WEATHER SERVICE MIAMI FL
1000Z [6 AM] WED SEP 20 1989

TROPICAL STORM WARNINGS IN EFFECT FOR CENTRAL AND NORTHWESTERN BAHAMAS AND DISCONTINUED FOR SOUTHEASTERN BAHAMAS.

HURRICANE CENTER LOCATED NEAR 24.9N 70.5W AT 20/1000Z.
POSITION ACCURATE WITHIN 15 MILES BASED ON AIRCRAFT AND SATELLITE.

PRESENT MOVEMENT TOWARDS THE NORTHWEST OR 325 DEGREES AT 11 KT.

DIAMETER OF EYE 15 NM.
MAX SUSTAINED WINDS 90 KT WITH GUSTS TO 105 KT.
RADIUS OF 64 KT WINDS 60NE 60SE 40SW 60NW.
RADIUS OF 50 KT WINDS 100NE 100SE 50SW 100NW.
RADIUS OF 34 KT WINDS 150NE 125SE 100SW 175NW.
RADIUS OF 12 FT SEAS OR HIGHER 150NE 125SE 100SW 175NW.

REPEAT CENTER LOCATED AT 24.9N 70.5W AT 20/1000Z.

FORECAST VALID 20/1800Z 26.0N 71.4W.
MAX SUSTAINED WINDS 90 KT WITH GUSTS TO 105 KT.
RADIUS OF 50 KT WINDS 100NE 100SE 50SW 100NW.
RADIUS OF 34 KT WINDS 150NE 125SE 100SW 175NW.

FORECAST VALID 21/0600Z 27.8N 72.9W.
MAX SUSTAINED WINDS 90 KT WITH GUSTS TO 105 KT.
RADIUS OF 50 KT WINDS 100NE 100SE 50SW 100NW.
RADIUS OF 34 KT WINDS 150NE 125SE 100SW 175NW.

(CONTINUED)

* This advisory was issued approximately 42 hours before Hurricane struck the South Carolina coast near midnight on September 21, 1989.

FORECAST VALID 21/1800Z 29.2N 74.8W.
MAX SUSTAINED WINDS 90 KT WITH GUSTS TO 105 KT.
RADIUS OF 50 KT WINDS 100NE 100SE 50SW 100NW.
RADIUS OF 34 KT WINDS 150NE 125SE 100SW 175NW.

REQUEST FOR 3 HOURLY SHIP REPORTS WITHIN 300 MILES OF 24.9N 70.5W.

EXTENDED OUTLOOK
THE FOLLOWlNG FORECASTS SHOULD BE USED ONLY FOR GUIDANCE PURPOSES BECAUSE ERRORS MAY EXCEED A FEW HUNDRED MILES

OUTLOOK VALID 22/0600Z 30.5N 78.0W.
MAX SUSTAINED WINDS 90 KT WITH GUSTS TO 105 KT.
RADIUS OF 50 KT WINDS 100NE 100SE 50SW 100NW.

OUTLOOK VALID 23/0600Z 33.5N 81.0W.
MAX SUSTAINED WINDS 60 KT WITH GUSTS TO 75 KT.
RADIUS OF 50 KT WINDS 100SE .
NEXT ADVlSORY AT 20/1600Z.

SAMPLE*
PUBLIC ADVISORY

88
MIATCPAT1
ETTAA00 KNHC 200925
BULLETIN
HURRICANE HUGO ADVISORY NUMBER 38
NATIONAL WEATHER SERVICE MIAMI FL
6 AM EDT WED SEP 20 1989

A TROPICAL STORM WARNING IS IN EFFECT FOR THE CENTRAL AND NORTHWESTERN BAHAMAS AND IS DISCONTINUED FOR THE SOUTHEASTERN BAHAMAS.

AT 6 AM EDT THE CENTER OF HUGO WAS LOCATED NEAR LATITUDE 24.9 NORTH LONGITUDE 70.5 WEST OR ABOUT 435 MILES EAST OF NASSAU IN THE BAHAMAS.

THE CENTER OF HUGO HAS BEEN MOVING TOWARD THE NORTHWEST AT 12 MPH AND THIS GENERAL MOTION IS EXPECTED TO CONTINUE FOR THE NEXT 24 HOURS.

MAXIMUM SUSTAINED WINDS ARE NEAR 105 MPH AND LITTLE CHANGE IN STRENGTH IS LIKELY TODAY. HURRICANE FORCE WINDS EXTEND OUTWARD UP TO 60 MILES FROM THE CENTER AND TROPICAL STORM FORCE WINDS EXTEND OUTWARD UP TO 200 MILES. THE LATEST MINIMUM PRESSURE REPORTED BY AN AIR FORCE RECONNAISSANCE PLANE IS 957 MILLIBARS...28.26 INCHES.

REPEATING THE 6 AM EDT POSITION...24.9N...70.5W. MOVEMENT... NORTHWESTWARD AT 12 MPH. MAXIMUM SUSTAINED WINDS...105 MPH. CENTRAL PRESSURE...957 MB.

THE NEXT ADVISORY WILL BE ISSUED BY THE NATIONAL HURRICANE CENTER AT NOON EDT WITH AN INTERMEDIATE ADVISORY AT 9 AM.

(CONTINUED)

* This advisory was issued approximately 42 hours before Hurricane struck the South Carolina coast near midnight on September 21, 1989.

ADVISORY NUMBER 38 HURRICANE HUGO PROBABILITIES
FOR GUIDANCE IN HURRICANE PROTECTION PLANNING
BY GOVERNMENT AND DISASTER OFFICIALS

CHANCES OF CENTER OF HUGO PASSING WITHIN 65 MILES OF
LISTED LOCATIONS THROUGH 2 AM EDT SAT SEP 23 1989
CHANCES EXPRESSED IN PER CENT...TIMES EDT

COASTAL LOCATIONS	THRU 2 AM THU	ADDITIONAL PROBABILITIES 2 AM THU THRU 2 PM THU	2 PM THU THRU 2 AM FRI	2 AM FRI THRU 2 AM SAT	TOTAL THRU 2 AM SAT
MYSM 241N 745W	1	2	X	1	4
MYEG 235N 758W	X	1	1	X	2
MYAK 241N 776W	X	1	1	1	3
MYNN 251N 775W	X	3	2	1	6
MYGF 266N 787W	X	3	5	2	10
MARATHON FL	X	X	2	2	4
MIAMI FL	X	1	3	2	6
W PALM BEACH FL	X	1	5	2	8
FT PIERCE FL	X	1	6	3	10
COCOA BEACH FL	X	1	7	3	11
DAYTONA BEACH FL	X	1	6	4	11
JACKSONVILLE FL	X	X	6	5	11
SAVANNAH GA	X	X	5	6	11
CHARLESTON SC	X	X	6	6	12
MYRTLE BEACH SC	X	X	6	5	11
WILMINGTON NC	X	X	5	6	11
MOREHEAD CITY NC	X	X	5	5	10
CAPE HATTERAS NC	X	X	4	5	9
NORFOLK VA	X	X	1	6	7
OCEAN CITY MD	X	X	X	5	5
ATLANTIC CITY NJ	X	X	X	4	4
NEW YORK CITY NY	X	X	X	3	3
MONTAUK POINT NY	X	X	X	2	2
PROVIDENCE RI	X	X	X	2	2
NANTUCKET MA	X	X	X	2	2

"X" MEANS LESS THAN ONE PERCENT

[NOTE: List of locations abbreviated; Gulf Coast locations omitted.]

TABLE 7-12
TIME CONVERSION TABLE

DATE	ZULU TIME [1]	EASTERN DAYLIGHT TIME [2] MILITARY TIME (24 HR)	EASTERN DAYLIGHT TIME [2] CIVIL TIME (AM/PM)	STANDARD TIME MILITARY TIME (24 HR)	STANDARD TIME CIVIL TIME (AM/PM)
1st	0500	(1st) 0100	(1st) 1 AM	(1st) 0000	(1st) 12 MIDNIGHT
	0600	0200	2 AM	(1st) 0100	(1st) 1 AM
	0700	0300	3 AM	0200	2 AM
	0800	0400	4 AM	0300	3 AM
	0900	0500	5 AM	0400	4 AM
	1000	0600	6 AM	0500	5 AM
	1100	0700	7 AM	0600	6 AM
	1200	0800	8 AM	0700	7 AM
	1300	0900	9 AM	0800	8 AM
	1400	1000	10 AM	0900	9 AM
	1500	1100	11 AM	1000	10 AM
	1600	1200	12 NOON	1100	11 AM
	1700	1300	1 PM	1200	12 NOON
	1800	1400	2 PM	1300	1 PM
	1900	1500	3 PM	1400	2 PM
	2000	1600	4 PM	1500	3 PM
	2100	1700	5 PM	1600	4 PM
	2200	1800	6 PM	1700	5 PM
	2300	1900	7 PM	1800	6 PM
2nd	0000	2000	8 PM	1900	7 PM
	0100	2100	9 PM	2000	8 PM
	0200	2200	10 PM	2100	9 PM
	0300	2300	11 PM	2200	10 PM
	0400	(2nd) 0000	12 MIDNIGHT	2300	11 PM
	0500	(2nd) 0100	(2nd) 1 AM	(2nd) 0000	(2nd) 12 MIDNIGHT

1. Zulu Time is also known as Greenwich Mean Time (GMT) and Universal Coordinated Time (UTC).

2. Eastern Daylight Time is also known as Atlantic Standard Time.

TABLE 7-13

SAFFIR/SIMPSON HURRICANE SCALE RANGES

SCALE NUMBER CATEGORY	CENTRAL PRESSURE		WINDS (mph)	WINDS (knots)	DAMAGE
	MILLIBARS	INCHES			
1	> 980	28.94	74 - 95	64 - 83	Minimal
2	965 - 979	28.50 - 28.91	96 - 110	84 - 96	Moderate
3	945 - 964	27.91 - 28.47	111 - 130	97 - 113	Extensive
4	920 - 944	27.17 - 27.88	131 - 155	114 - 135	Extreme
5*	920	27.17	>155	>135	Catastrophic

*NOTE: Category 5 is not considered in the Maryland Hurricane Evacuation Study.

TABLE 7-1

DECISION ARCS
ANNE ARUNDEL COUNTY *

Storm Category/Speed (Knots)	Evacuee Response	Clearance Time in Hours/Decision Arcs Off-Season Occupancy	Peak-Season Occupancy
CAT 1-2/5	Rapid	9.25/C	17.75/E
CAT 1-2/5	Medium	11.75/C	19.75/E
CAT 1-2/5	Slow	15.75/D	22.50/F
CAT 1-2/10	Rapid	9.25/E	17.75/I
CAT 1-2/10	Medium	11.75/F	19.75/J
CAT 1-2/10	Slow	15.75/H	22.50/L
CAT 1-2/15	Rapid	9.25/G	17.75/N
CAT 1-2/15	Medium	11.75/I	19.75/O
CAT 1-2/15	Slow	15.75/L	22.50/Q
CAT 1-2/20	Rapid	9.25/J	17.75/R
CAT 1-2/20	Medium	11.75/L	19.75/T
CAT 1-2/20	Slow	15.75/P	22.50/W
CAT 1-2/30	Rapid	9.25/N	17.75/AA
CAT 1-2/30	Medium	11.75/R	19.75/DD
CAT 1-2/30	Slow	15.75/X	22.50/EE+
CAT 3-4/5	Rapid	10.25/C	20.50/F
CAT 3-4/5	Medium	13.00/D	22.25/F
CAT 3-4/5	Slow	17.25/E	25.25/G
CAT 3-4/10	Rapid	10.25/E	20.50/K
CAT 3-4/10	Medium	13.00/G	22.25/L
CAT 3-4/10	Slow	17.25/I	25.25/M
CAT 3-4/15	Rapid	10.25/H	20.50/P
CAT 3-4/15	Medium	13.00/J	22.25/Q
CAT 3-4/15	Slow	17.25/M	25.25/S
CAT 3-4/20	Rapid	10.25/K	20.50/U
CAT 3-4/20	Medium	13.00/M	22.25/W
CAT 3-4/20	Slow	17.25/R	25.25/Z
CAT 3-4/30	Rapid	10.25/P	20.50/EE
CAT 3-4/30	Medium	13.00/T	22.25/EE+
CAT 3-4/30	Slow	17.25/Z	25.25/EE+

* Note: Decision Arcs for Anne Arundel County are determined by using the highest clearance time for each seasonal occupation.

TABLE 7-2

DECISION ARCS
CAROLINE COUNTY

Storm Category/Speed (Knots)	Evacuee Response	Clearance Time in Hours/Decision Arcs Off-Season Occupancy	Peak-Season Occupancy
CAT 1-4/5	Rapid	12.50/D	18.00/E
CAT 1-4/5	Medium	13.50/D	19.00/E
CAT 1-4/5	Slow	15.00/D	20.25/F
CAT 1-4/10	Rapid	12.50/G	18.00/I
CAT 1-4/10	Medium	13.50/G	19.00/J
CAT 1-4/10	Slow	15.00/H	20.25/K
CAT 1-4/15	Rapid	12.50/J	18.00/N
CAT 1-4/15	Medium	13.50/K	19.00/O
CAT 1-4/15	Slow	15.00/L	20.25/P
CAT 1-4/20	Rapid	12.50/M	18.00/R
CAT 1-4/20	Medium	13.50/N	19.00/S
CAT 1-4/20	Slow	15.00/O	20.25/U
CAT 1-4/30	Rapid	12.50/S	18.00/AA
CAT 1-4/30	Medium	13.50/U	19.00/CC
CAT 1-4/30	Slow	15.00/W	20.25/EE

TABLE 7-3

DECISION ARCS
DORCHESTER COUNTY

Storm Category/Speed (Knots)	Evacuee Response	Clearance Time in Hours/Decision Arcs			
		Low Occupancy	Medium Occupancy	High Occupancy	Worst Case Occupancy
CAT 1/5	Rapid	5.50/B	11.75/C	16.25/E	20.50/F
CAT 1/5	Medium	6.25/B	12.25/D	16.50/E	20.75/F
CAT 1/5	Slow	9.00/C	13.00/D	17.25/E	21.50/F
CAT 1/10	Rapid	5.50/C	11.75/F	16.25/I	20.50/K
CAT 1/10	Medium	6.25/D	12.25/G	16.50/I	20.75/K
CAT 1/10	Slow	9.00/E	13.00/G	17.25/I	21.50/K
CAT 1/15	Rapid	5.50/E	11.75/I	16.25/M	20.50/P
CAT 1/15	Medium	6.25/E	12.25/J	16.50/M	20.75/P
CAT 1/15	Slow	9.00/G	13.00/J	17.25/M	21.50/Q
CAT 1/20	Rapid	5.50/F	11.75/L	16.25/Q	20.50/U
CAT 1/20	Medium	6.25/G	12.25/M	16.50/Q	20.75/U
CAT 1/20	Slow	9.00/I	13.00/M	17.25/R	21.50/V
CAT 1/30	Rapid	5.50/I	11.75/R	16.25/Y	20.50/EE
CAT 1/30	Medium	6.25/J	12.25/S	16.50/Y	20.75/EE+
CAT 1/30	Slow	9.00/N	13.00/T	17.25/Z	21.50/EE+
CAT 2-4/5	Rapid	7.50/B	15.50/D	20.75/F	24.00/F
CAT 2-4/5	Medium	8.00/B	15.75/D	21.25/F	24.25/G
CAT 2-4/5	Slow	9.25/C	16.50/E	21.75/F	24.75/G
CAT 2-4/10	Rapid	7.50/D	15.50/H	20.75/K	24.00/L
CAT 2-4/10	Medium	8.00/D	15.75/H	21.25/K	24.25/M
CAT 2-4/10	Slow	9.25/E	16.50/I	21.75/K	24.75/M
CAT 2-4/15	Rapid	7.50/F	15.50/L	20.75/P	24.00/R
CAT 2-4/15	Medium	8.00/F	15.75/L	21.25/P	24.25/S
CAT 2-4/15	Slow	9.25/G	16.50/M	21.75/Q	24.75/S
CAT 2-4/20	Rapid	7.50/H	15.50/P	20.75/U	24.00/X
CAT 2-4/20	Medium	8.00/H	15.75/P	21.25/V	24.25/Y
CAT 2-4/20	Slow	9.25/J	16.50/Q	21.75/V	24.75/Y
CAT 2-4/30	Rapid	7.50/L	15.50/X	20.75/EE+	24.00/EE+
CAT 2-4/30	Medium	8.00/L	15.75/X	21.25/EE+	24.25/EE+
CAT 2-4/30	Slow	9.25/N	16.50/Y	21.75/EE+	24.75/EE+

TABLE 7-4

DECISION ARCS
KENT COUNTY

Storm Category/Speed (Knots)	Evacuee Response	Clearance Time in Hours/Decision Arcs
CAT 1-4/5	Rapid	4.25/B
CAT 1-4/5	Medium	6.25/B
CAT 1-4/5	Slow	9.25/C
CAT 1-4/10	Rapid	4.25/C
CAT 1-4/10	Medium	6.25/D
CAT 1-4/10	Slow	9.25/E
CAT 1-4/15	Rapid	4.25/D
CAT 1-4/15	Medium	6.25/E
CAT 1-4/15	Slow	9.25/G
CAT 1-4/20	Rapid	4.25/E
CAT 1-4/20	Medium	6.25/G
CAT 1-4/20	Slow	9.25/J
CAT 1-4/30	Rapid	4.25/G
CAT 1-4/30	Medium	6.25/K
CAT 1-4/30	Slow	9.25/N

TABLE 7-5

DECISION ARCS
QUEEN ANNE'S COUNTY

Storm Category/Speed (Knots)	Evacuee Response	Clearance Time in Hours/Decision Arcs: Low Occupancy	Medium Occupancy	High Occupancy	Worst Case Occupancy
CAT 1-2/5	Rapid	11.50/C	19.00/E	26.50/G	31.25/H
CAT 1-2/5	Medium	12.25/D	19.75/E	27.00/G	32.00/H
CAT 1-2/5	Slow	13.00/D	20.50/F	28.00/G	32.75/I
CAT 1-2/10	Rapid	11.50/F	19.00/J	26.50/N	31.25/P
CAT 1-2/10	Medium	12.25/G	19.75/J	27.00/N	32.00/P
CAT 1-2/10	Slow	13.00/G	20.50/K	28.00/N	32.75/Q
CAT 1-2/15	Rapid	11.50/I	19.00/O	26.50/T	31.25/X
CAT 1-2/15	Medium	12.25/J	19.75/O	27.00/U	32.00/X
CAT 1-2/15	Slow	13.00/J	20.50/P	28.00/U	32.75/Y
CAT 1-2/20	Rapid	11.50/L	19.00/S	26.50/AA	31.25/EE+
CAT 1-2/20	Medium	12.25/M	19.75/T	27.00/AA	32.00/EE+
CAT 1-2/20	Slow	13.00/M	20.50/U	28.00/BB	32.75/EE+
CAT 1-2/30	Rapid	11.50/R	19.00/CC	26.50/EE+	31.25/EE+
CAT 1-2/30	Medium	12.25/S	19.75/DD	27.00/EE+	32.00/EE+
CAT 1-2/30	Slow	13.00/T	20.50/EE	28.00/EE+	32.75/EE+
CAT 3-4/5	Rapid	15.00/D	24.50/G	32.75/I	36.25/J
CAT 3-4/5	Medium	15.50/D	24.75/G	33.25/I	36.75/J
CAT 3-4/5	Slow	16.50/E	25.50/G	34.00/I	37.50/J
CAT 3-4/10	Rapid	15.00/H	24.50/M	32.75/Q	36.25/S
CAT 3-4/10	Medium	15.50/H	24.75/M	33.25/Q	36.75/S
CAT 3-4/10	Slow	16.50/I	25.50/M	34.00/Q	37.50/S
CAT 3-4/15	Rapid	15.00/L	24.50/S	32.75/Y	36.25/BB
CAT 3-4/15	Medium	15.50/L	24.75/S	33.25/Y	36.75/BB
CAT 3-4/15	Slow	16.50/M	25.50/T	34.00/Z	37.50/CC
CAT 3-4/20	Rapid	15.00/O	24.50/Y	32.75/EE+	36.25/EE+
CAT 3-4/20	Medium	15.50/P	24.75/Y	33.25/EE+	36.75/EE+
CAT 3-4/20	Slow	16.50/Q	25.50/Z	34.00/EE+	37.50/EE+
CAT 3-4/30	Rapid	15.00/W	24.50/EE+	32.75/EE+	36.25/EE+
CAT 3-4/30	Medium	15.50/X	24.75/EE+	33.25/EE+	36.75/EE+
CAT 3-4/30	Slow	16.50/Y	25.50/EE+	34.00/EE+	37.50/EE+

TABLE 7-6

DECISION ARCS
ST. MARY'S COUNTY

Storm Category/Speed (Knots)	Evacuee Response	Clearance Time in Hours/Decision Arcs
CAT 1-4/5	Rapid	4.25/B
CAT 1-4/5	Medium	6.25/B
CAT 1-4/5	Slow	9.25/C
CAT 1-4/10	Rapid	4.25/C
CAT 1-4/10	Medium	6.25/D
CAT 1-4/10	Slow	9.25/E
CAT 1-4/15	Rapid	4.25/D
CAT 1-4/15	Medium	6.25/E
CAT 1-4/15	Slow	9.25/G
CAT 1-4/20	Rapid	4.25/E
CAT 1-4/20	Medium	6.25/G
CAT 1-4/20	Slow	9.25/J
CAT 1-4/30	Rapid	4.25/G
CAT 1-4/30	Medium	6.25/K
CAT 1-4/30	Slow	9.25/N

TABLE 7-7

DECISION ARCS
SOMERSET COUNTY

Storm Category/Speed (Knots)	Evacuee Response	Clearance Time in Hours/Decision Arcs: Off-Season Occupancy	Peak-Season Occupancy
CAT 1/5	Rapid	6.50/B	10.75/C
CAT 1/5	Medium	7.25/B	11.75/C
CAT 1/5	Slow	9.00/C	13.00/D
CAT 1/10	Rapid	6.50/D	10.75/F
CAT 1/10	Medium	7.25/D	11.75/F
CAT 1/10	Slow	9.00/E	13.00/G
CAT 1/15	Rapid	6.50/E	10.75/I
CAT 1/15	Medium	7.25/F	11.75/I
CAT 1/15	Slow	9.00/G	13.00/J
CAT 1/20	Rapid	6.50/G	10.75/K
CAT 1/20	Medium	7.25/H	11.75/L
CAT 1/20	Slow	9.00/I	13.00/M
CAT 1/30	Rapid	6.50/J	10.75/Q
CAT 1/30	Medium	7.25/K	11.75/R
CAT 1/30	Slow	9.00/N	13.00/T
CAT 2-3/5	Rapid	11.00/C	13.25/D
CAT 2-3/5	Medium	11.50/C	13.75/D
CAT 2-3/5	Slow	12.50/D	14.75/D
CAT 2-3/10	Rapid	11.00/F	13.25/G
CAT 2-3/10	Medium	11.50/F	13.75/G
CAT 2-3/10	Slow	12.50/G	14.75/H
CAT 2-3/15	Rapid	11.00/I	13.25/J
CAT 2-3/15	Medium	11.50/I	13.75/K
CAT 2-3/15	Slow	12.50/J	14.75/L
CAT 2-3/20	Rapid	11.00/K	13.25/N
CAT 2-3/20	Medium	11.50/L	13.75/N
CAT 2-3/20	Slow	12.50/M	14.75/O
CAT 2-3/30	Rapid	11.00/Q	13.25/T
CAT 2-3/30	Medium	11.50/R	13.75/U
CAT 2-3/30	Slow	12.50/S	14.75/W

TABLE 7-7 (Continued)
DECISION ARCS
SOMERSET COUNTY

Storm Category/Speed (Knots)	Evacuee Response	Clearance Time in Hours/Decision Arcs	
		Off-Season Occupancy	Peak-Season Occupancy
CAT 4/5	Rapid	11.50/C	13.75/D
CAT 4/5	Medium	12.00/C	14.25/D
CAT 4/5	Slow	13.00/D	15.00/D
CAT 4/10	Rapid	11.50/F	13.75/G
CAT 4/10	Medium	12.00/F	14.25/H
CAT 4/10	Slow	13.00/G	15.00/H
CAT 4/15	Rapid	11.50/I	13.75/K
CAT 4/15	Medium	12.00/I	14.25/K
CAT 4/15	Slow	13.00/J	15.00/L
CAT 4/20	Rapid	11.50/L	13.75/N
CAT 4/20	Medium	12.00/L	14.25/O
CAT 4/20	Slow	13.00/M	15.00/O
CAT 4/30	Rapid	11.50/R	13.75/U
CAT 4/30	Medium	12.00/R	14.25/V
CAT 4/30	Slow	13.00/T	15.00/W

TABLE 7-8

DECISION ARCS
TALBOT COUNTY

Storm Category/Speed (Knots)	Evacuee Response	Clearance Time in Hours/Decision Arcs Low Occupancy	Medium Occupancy	High Occupancy	Worst Case Occupancy
CAT 1/5	Rapid	9.75/C	21.25/F	28.75/H	36.00/I
CAT 1/5	Medium	10.25/C	21.75/F	29.50/H	36.75/J
CAT 1/5	Slow	11.50/C	22.75/F	30.50/H	37.50/J
CAT 1/10	Rapid	9.75/E	21.25/K	28.75/O	36.00/R
CAT 1/10	Medium	10.25/F	21.75/K	29.50/O	36.75/S
CAT 1/10	Slow	11.50/F	22.75/L	30.50/P	37.50/S
CAT 1/15	Rapid	9.75/H	21.25/P	28.75/V	36.00/AA
CAT 1/15	Medium	10.25/H	21.75/Q	29.50/W	36.75/BB
CAT 1/15	Slow	11.50/I	22.75/R	30.50/W	37.50/CC
CAT 1/20	Rapid	9.75/J	21.25/V	28.75/CC	36.00/EE+
CAT 1/20	Medium	10.25/K	21.75/V	29.50/DD	36.75/EE+
CAT 1/20	Slow	11.50/L	22.75/W	30.50/EE	37.50/EE+
CAT 1/30	Rapid	9.75/O	21.25/EE+	28.75/EE+	36.00/EE+
CAT 1/30	Medium	10.25/P	21.75/EE+	29.50/EE+	36.75/EE+
CAT 1/30	Slow	11.50/R	22.75/EE+	30.50/EE+	37.50/EE+
CAT 2-4/5	Rapid	14.25/D	28.25/H	37.50/J	42.75/K
CAT 2-4/5	Medium	15.00/D	28.75/H	38.25/J	43.50/K
CAT 2-4/5	Slow	16.00/D	29.75/H	39.00/J	44.50/L
CAT 2-4/10	Rapid	14.25/H	28.25/O	37.50/S	42.75/V
CAT 2-4/10	Medium	15.00/H	28.75/O	38.25/T	43.50/V
CAT 2-4/10	Slow	16.00/H	29.75/O	39.00/T	44.50/W
CAT 2-4/15	Rapid	14.25/K	28.25/V	37.50/CC	42.75/EE+
CAT 2-4/15	Medium	15.00/L	28.75/V	38.25/CC	43.50/EE+
CAT 2-4/15	Slow	16.00/L	29.75/W	39.00/DD	44.50/EE+
CAT 2-4/20	Rapid	14.25/O	28.25/CC	37.50/EE+	42.75/EE+
CAT 2-4/20	Medium	15.00/O	28.75/CC	38.25/EE+	43.50/EE+
CAT 2-4/20	Slow	16.00/P	29.75/DD	39.00/EE+	44.50/EE+
CAT 2-4/30	Rapid	14.25/V	28.25/EE+	37.50/EE+	42.75/EE+
CAT 2-4/30	Medium	15.00/W	28.75/EE+	38.25/EE+	43.50/EE+
CAT 2-4/30	Slow	16.00/X	29.75/EE+	39.00/EE+	44.50/EE+

TABLE 7-9

DECISION ARCS
WICOMICO COUNTY

Storm Category/Speed (Knots)	Evacuee Response	Clearance Time in Hours/Decision Arcs Low Occupancy	Medium Occupancy	High Occupancy	Worst Case Occupancy
CAT 1/5	Rapid	8.25/C	17.50/E	24.00/F	30.00/H
CAT 1/5	Medium	9.50/C	18.75/E	25.00/G	31.00/H
CAT 1/5	Slow	11.25/C	20.50/F	27.00/G	33.00/I
CAT 1/10	Rapid	8.25/E	17.50/I	24.00/L	30.00/O
CAT 1/10	Medium	9.50/E	18.75/J	25.00/M	31.00/P
CAT 1/10	Slow	11.25/F	20.50/K	27.00/N	33.00/Q
CAT 1/15	Rapid	8.25/G	17.50/N	24.00/R	30.00/W
CAT 1/15	Medium	9.50/H	18.75/O	25.00/S	31.00/X
CAT 1/15	Slow	11.25/I	20.50/P	27.00/U	33.00/Y
CAT 1/20	Rapid	8.25/I	17.50/R	24.00/X	30.00/DD
CAT 1/20	Medium	9.50/J	18.75/S	25.00/Y	31.00/EE
CAT 1/20	Slow	11.25/L	20.50/U	27.00/AA	33.00/EE+
CAT 1/30	Rapid	8.25/M	17.50/AA	24.00/EE+	30.00/EE+
CAT 1/30	Medium	9.50/O	18.75/CC	25.00/EE+	31.00/EE+
CAT 1/30	Slow	11.25/Q	20.50/EE	27.00/EE+	33.00/EE+
CAT 2-4/5	Rapid	10.75/C	22.25/F	30.00/H	34.25/I
CAT 2-4/5	Medium	12.00/C	23.50/F	31.25/H	35.50/I
CAT 2-4/5	Slow	13.75/D	25.25/G	33.00/I	37.25/J
CAT 2-4/10	Rapid	10.75/F	22.25/L	30.00/O	34.25/R
CAT 2-4/10	Medium	12.00/F	23.50/L	31.25/P	35.50/R
CAT 2-4/10	Slow	13.75/G	25.25/M	33.00/Q	37.25/S
CAT 2-4/15	Rapid	10.75/I	22.25/Q	30.00/W	34.25/Z
CAT 2-4/15	Medium	12.00/I	23.50/R	31.25/X	35.50/AA
CAT 2-4/15	Slow	13.75/K	25.25/S	33.00/Y	37.25/BB
CAT 2-4/20	Rapid	10.75/K	22.25/W	30.00/DD	34.25/EE+
CAT 2-4/20	Medium	12.00/L	23.50/X	31.25/EE+	35.50/EE+
CAT 2-4/20	Slow	13.75/N	25.25/Z	33.00/EE+	37.25/EE+
CAT 2-4/30	Rapid	10.75/Q	22.25/EE+	30.00/EE+	34.25/EE+
CAT 2-4/30	Medium	12.00/R	23.50/EE+	31.25/EE+	35.50/EE+
CAT 2-4/30	Slow	13.75/U	25.25/EE+	33.00/EE+	37.25/EE+

TABLE 7-10

DECISION ARCS
WORCESTER COUNTY AND OCEAN CITY

Storm Category/Speed (Knots)	Evacuee Response	Clearance Time in Hours/Decision Arcs			
		Low Occupancy	Medium Occupancy	High Occupancy	Worst Case
CAT 1-2/5	Rapid	4.00/A	8.00/B	11.00/C	14.00/D
CAT 1-2/5	Medium	6.00/B	8.75/C	11.50/C	14.50/D
CAT 1-2/5	Slow	9.00/C	9.75/C	12.50/D	15.00/D
CAT 1-2/10	Rapid	4.00/B	8.00/D	11.00/F	14.00/G
CAT 1-2/10	Medium	6.00/C	8.75/E	11.50/F	14.50/H
CAT 1-2/10	Slow	9.00/E	9.75/E	12.50/G	15.00/H
CAT 1-2/15	Rapid	4.00/C	8.00/F	11.00/I	14.00/K
CAT 1-2/15	Medium	6.00/E	8.75/G	11.50/I	14.50/K
CAT 1-2/15	Slow	9.00/G	9.75/H	12.50/J	15.00/L
CAT 1-2/20	Rapid	4.00/D	8.00/H	11.00/K	14.00/N
CAT 1-2/20	Medium	6.00/F	8.75/I	11.50/L	14.50/O
CAT 1-2/20	Slow	9.00/I	9.75/J	12.50/M	15.00/O
CAT 1-2/30	Rapid	4.00/F	8.00/L	11.00/Q	14.00/U
CAT 1-2/30	Medium	6.00/I	8.75/N	11.50/R	14.50/V
CAT 1-2/30	Slow	9.00/N	9.75/O	12.50/S	15.00/W
CAT 3-4/5	Rapid	4.00/A	10.25/C	14.00/D	22.00/F
CAT 3-4/5	Medium	6.00/B	10.75/C	14.50/D	22.25/F
CAT 3-4/5	Slow	9.00/C	11.75/C	15.00/D	22.50/F
CAT 3-4/10	Rapid	4.00/B	10.25/F	14.00/G	22.00/K
CAT 3-4/10	Medium	6.00/C	10.75/F	14.50/H	22.25/L
CAT 3-4/10	Slow	9.00/E	11.75/F	15.00/H	22.50/L
CAT 3-4/15	Rapid	4.00/C	10.25/H	14.00/K	22.00/Q
CAT 3-4/15	Medium	6.00/E	10.75/I	14.50/K	22.25/Q
CAT 3-4/15	Slow	9.00/G	11.75/I	15.00/L	22.50/Q
CAT 3-4/20	Rapid	4.00/D	10.25/K	14.00/N	22.00/V
CAT 3-4/20	Medium	6.00/F	10.75/K	14.50/O	22.25/W
CAT 3-4/20	Slow	9.00/I	11.75/L	15.00/O	22.50/W
CAT 3-4/30	Rapid	4.00/F	10.25/P	14.00/U	22.00/EE+
CAT 3-4/30	Medium	6.00/I	10.75/Q	14.50/V	22.25/EE+
CAT 3-4/30	Slow	9.00/N	11.75/R	15.00/W	22.50/EE+